MADRAS AGRICULTURAL DEPARTMENT

YEAR BOOK, 1919.

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YEAR BOOK, 1919.

RICE (*ORYZA SATIVA*) AT SAMALKOTA AGRICULTURAL STATION.

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Work on the rice crop at Samalkota * Agricultural Station was begun in 1907 by Mr. R. C. Wood, then Deputy Director of Agriculture, Northern Division, who was followed by the writer in 1910 who carried on the work until 1918 when his connexion with this station ended. Work is still in progress.

The information embodied in this paper will be found in the annual reports of the station and refers only to such experiments as were begun and completed during the period June 1907—June 1918. The main object of this paper is to collect this information in a more condensed and convenient form.

The experiments carried out may most conveniently be classed under the heads, cultural, manurial and varietal, in which order they will be dealt with.

The following extract † describes the local conditions to which the experiments had direct reference :—

"Paddy is cultivated in two seasons (1) extending from May-June to November and called

* Longitude 82° E. Latitude 17° N.
† Appendix 1—Samalkota Agricultural Station Report for 1916–17.

the *tolakari* season and (2) extending from January to May and called the *dalawa* season. For the first crop the seed-beds are usually sown in May with the help of early rains. The seed-beds are well manured and are generally sown very thickly, the commonest rate being 100 kuntsams (700 lb.) per acre of seed-bed.

"The land is prepared for the crop in June-July with the aid of water from the canal. Usually three ploughings are given. For the first, the land is moistened or advantage is taken of a shower of rain. For the second and third, the land is kept under water. These three ploughings are done at short intervals from one another and are usually scamped, as the cultivator depends on the continuous flooding given later to kill the weeds.

"In some parts where the land is low-lying, ploughing begins shortly after the removal of the first crop and is kept up until the transplanting season comes round again. In this case no second crop is taken and the operation of puddling (ploughing under water) is omitted. This practice is adopted because these lands when irrigated become very soft and it is difficult to plough owing to the depth to which the cattle sink into the ground.

"After the land is puddled, it is usually levelled with a levelling board drawn behind a pair of bullocks and the seedlings are transplanted in bunches of 4 to 20. An acre of seed-bed will transplant anything from 13 to 20 acres. Irrigation is then given at short intervals until about ten days before harvest which occurs in November-December.

"For the second crop, the seed-bed is generally puddled and the seed sprouted before sowing. This is done in January and the seedlings are transplanted a month later. The other operations are similar to those done for the first crop. Harvest takes place in May.

"Many ryots, however, do not care to crop the whole of their land twice with paddy and also the opportunity to do so is not always given, as the supply of water is not sufficient for all and the villages have to take turns. In such cases the land is sometimes left uncultivated and allowed to produce a crop of weeds which it does abundantly, or just before the harvest of paddy, horse-gram (*Dolichos biflorus*), sunnhemp (*Crotolaria juncea*), green-gram (*Phaseolus mungo*) or black-gram (Phas. radiatus) is sown. These occupy the ground after the removal of the paddy until February when the grams are harvested and sunnhemp is either cut for fodder or is grazed off by cattle. Sometimes after the harvest of the paddy, the land is ploughed and gingelly (*Sesamum indicum*) is sown in January and harvested in April. In this last case, a light irrigation is given when the gingelly is in flower and a creeping variety of green-gram is sown broadcast. This crop occupies the land after the removal of the gingelly and is ploughed in as green manure."

A statement showing the annual rainfall during the period 1905 to 1918 will be found in the appendix. The soil of this station is a heavy black alluvium.

Cultural experiments.—These experiments dealt with—

(1) The seed-bed period.	(*a*) Rate of sowing. (*b*) The age which the seedling was allowed to attain before being transplanted.
(2) Preparation of the field for the crop.	(*c*) Leaving the land ploughed or unploughed during the hot weather fallow. (*d*) Planting without puddling or after puddling.
(3) Time of planting ...	(*e*) Early or late in the season for the first crop. (*f*) Before the season for the second crop.
(4) Method of planting.	(*g*) Transplanting once or twice. (*h*) One or two seedlings per hole and at different distances apart.

(1) *Seed-bed period*—(*a*) *Seed-rate.*—This experiment was started in 1909 and was a direct outcome of experiment (*h*). While carrying out the latter it was found that the seedlings taken from seed-beds sown at the local seed-rate were so thickly placed and their roots were so matted together that it was not possible to separate them readily. It was, therefore, decided to try the effect of reducing the seed-rate. During the first two years, the local seed-rate, 700 lb. per acre of seed-bed, was taken as the standard and compared with

half this rate, the plots being laid down in duplicate.

In 1911, another plot transplanted from a seed-bed sown at the rate of 280 lb. per acre was added to this series. In 1912, the local seed-rate plot was dropped and in its place one transplanted from a bed sown at the rate of 210 lb. per acre and was introduced. In this final form the experiment was carried on until 1914, after which it was discontinued. The following table shows the results obtained over the whole period :—

Year.	Seed-rate.	Area of plot.*	Area of bed per acre of crop.	Yield * †
1909	700	23	Not recorded.	2,797/4,339
	...	...		2,947/3,956
	350	...		3,067/3,391
	...			2,916/3,271
1910	700	15	Not recorded.	2,660/4,771
	...	16		2,546/4,438
	350	15½		3,161/5,025
	...	17		2,552/4,064
1911	700	16¼	Not recorded.	2,701/3,963
	350	16¼		3,169/3,865
	280	16¼		3,329/3,908
1912	350	20	4·5	3,670/6,360
	280	20	5·5	3,640/6,935
	210	20	7·0	4,054/6,225
1913	350	20	3·4	3,115/8,050
	280	20	3·4	3,553/7,760
	210	20	3·4	4,290/9,260
1914	350	6¼	3·8	3,838/4,240
	...	12½	...	3,624/4,840
	...	12½	...	3,820/5,264
	280	6¼	...	3,952/3,760
	...	12½	...	3,688/4,960
	...	12½	...	3,716/5,360
	210	6¼	4·4	3,816/3,856
	...	12½	...	3,680/3,856
	...	12½	...	4,048/6,360

* Unless otherwise stated, areas are in cents and yields in pound per acre.
† Numerator denotes grain and the denominator straw.

The experiment was carried on for six years and in three different fields. From 1910 to 1913 inclusive, the same field was used. In all twenty-six plots were laid down.

As the results showed that in addition to the saving of seed, not only was there no diminution in yield, but that rather an increase, consequent upon the seedlings from the thinly sown beds being healthier and sturdier, was to be expected, the experiment was discontinued.

It would have been of interest to have carried on the experiment and determined the magnitude of the difference. This, however, would have involved the laying down of a large number of plots, a proceeding which the resources of the station would not at that time have permitted without interfering with other work.

(*b*) *Age of seedling.*—This experiment was begun in 1908 with the laying down of duplicate plots planted on the same day with seedlings 30 and 56 days old, respectively. This arrangement was reversed in the following year. The whole seed-bed was sown on the same day and 25, 35 and 45 days later seedlings were pulled out and planted in comparative plots. In 1910, the original arrangement was reverted to. Seed-beds were sown at intervals of ten days and when the oldest seedlings were 45 days old all the plots were transplanted on the same day. This plan was adhered to in 1911.

From 1912 until 1914 when the experiment was dropped both arrangements were adopted, i.e., sowing beds on the same day and transplanting on different days and sowing beds on different dates and transplanting on the same day.

The results were as follows:—

Year.	Area of plot.	Age of seedling days.	Seed-beds sown on the same date and the seedlings transplanted on different dates.	Seed-beds sown on different dates and seedlings transplanted on the same day.
1908 ...	34 ; 67	56	......	1,879/2,029 ; 2,478/2,702
	36 ; 76	30	......	1,864/2,131 ; 1,765/2,232
1909 ...	29	45	3,916/4,325	......
	29	35	3,279/4,715	......
	29	25	3,220/4,845	......
1910 ...	24 ; 22	45	......	2,872/4,872 ; 2,887/4,547
	27 ; 24	35	......	2,244/4,015 ; 2,278/3,529
	29 ; 27	25	......	2,027/3,555 ; 1,892/3,214 *
1911 ...	20	45	......	2,560/4,015 ; 3,205/3,975
	20	35	......	2,880/4,325 ; 3,170/3,415
	20	25	......	2,080/3,175 ; 2,355/3,375
1912 ...	20	45	3,821/6,271	3,295/4,825
	20	35	3,700/5,865	3,640/4,875
	20	25	4,050/5,300	4,190/6,075
1913 ...	$16\frac{2}{3}$	45	3,756/7,866	3,546/8,448
	$16\frac{2}{3}$	35	3,900/8,184	3,564/6,312
	$16\frac{2}{3}$	25	4,122/5,760	4,074/7,134
1914 ..	5	45	3,420/5,480; 3,340/4,760; 3,580/4,520.	3,680/4,340 ; 3,360/6,160 ; 3,820/5,240.
	5	35	3,280/4,860; 3,940/6,400; 3,800/4,820.	3,360/5,500 ; 3,120/5,180 ; 3,940/5,440.
	5	25	3,520/5,140; 4,500/6,460 ; 3,900/5,460.	3,700/5,440 ; 3,080/4,500 ; 3,760/4,780.

* Crop lodged.

Taking the yield from 1909 and onwards and omitting the low yield of the duplicate 25 day plot in 1910, the average yield of grain per acre, keeping the same order adopted in the table, works to 3,475, 3,340 and 3,404 lb. respectively. The probable error for the same plots is 12 per cent. As the differences between these averages fall well within the limits of error, the conclusion that, as far as yield is concerned, it is a matter of small moment whether the seedlings are 25, 35, or 45 days old at time of planting is justified.

In accepting this conclusion however it must be borne in mind that throughout the experiment care was taken to see that planting was done in good time. Even so it was observed that the oldest seedlings always took longer to establish themselves and always suffered more casualties.

(2) *Preparation of the field for the crop—(c) Cultivated and uncultivated fallow.*—The object of this experiment was to discover whether the thorough heating and drying out that the soil would receive by lying in a rough condition through the hot weather, when the maximum daily temperature in the shade usually stands at 104°F would not have the same sterilizing effect as that reported by experimenters elsewhere.

The experiment was begun in 1911 and carried on for four years. Two fields were taken and divided into two equal parts. After the harvest of the first crop of paddy one-half of each was broken up and the other left untouched. During the first two years cultivation was done by means of the plough but as in the second year this proved unsatisfactory, crowbarring was resorted to for the last two years of the experiment.

It was evident from the appearance of the crop that the cultivation had had some effect, apart from the incidental one of keeping down weeds. In every case the crop on the cultivated plots appeared thinner and did not cover the ground so well as that on their comparatives. From the results shown below it will be seen that in one case only was the yield from a cultivated plot higher than from its comparative uncultivated one.

The exact cause of the depression in yield was not inquired into. A probable explanation is that the expected sterilization did take place, but that under the anærobic conditions which prevailed when the crop was put in the accumulated nitrates were decomposed, with the liberation of free nitrogen. The final result being that the soil was depleted of instead of becoming richer in nitrogen.

Year.	Area of plot.	Yield.	
		Cultivated fallow.	Uncultivated fallow.
1911	60	1,965/2,745	2,289/3,311
	20	2,516/2,856	3,091/3,800
1912	60	3,736/6,184	3,297/7,236
	20	3,287/5,709	3,515/4,756
1913	60	2,649/3,852	3,158/5,095
	20	2,985/4,120	3,616/3,732
1914	30	3,307/6,367 3,167/7,150	3,700/6,383 3,443/7,557
	10	2,010/5,330 2,170/4,750	3,600/4,750 3,180/4,450

(*d*) *Planting after and without puddling.*—This experiment was begun in 1909 and was carried on for four years with the following results:—

Year.	Area of plot.	Yield.	
		Puddled.	Non-puddled.
1909	30	4,160/5,056	2,883/3,583
	55	3,572/4,543	3,467/4,429
1910	60	3,097/3,977	3,123/5,547
	48	2,981/5,288	3,238/4,258
1911	60	3,304/4,570	2,705/3,450
	48	2,950/4,152	2,471/3,231
1912	48	3,877/6,356	3,544/4,393

This experiment was similar to experiment (*c*) to the extent that during the period between the harvest of the first crop of one season and the planting of the first crop of the next, the non-puddled plot was cultivated and the puddled plot was left undisturbed. In this case, however, cultivation was done with a country plough and was not therefore nearly so well done as when the land was crowbarred. The drying out of the soil was not so thorough. Nevertheless the crop on the non-puddled plot behaved in a very similar manner to that on the cultivated plots in experiment (*c*).

It will be seen from the results quoted above that except in 1910 the yield from the cultivated and non-puddled plots were lower than those from their comparatives. That this was not also the case in 1910 was due to the fact that the crop on the puddled plots grew very much more vigorously than that on the non-puddled plots and lodged much earlier, thereby reducing the yield.

Taking this into account and also the fact that weeds became troublesome when puddling was not done, it was concluded that it is advisable to puddle the land if this operation is at all possible.

(3) *Time of planting—(e) Early or late in the season for the first crop.*—This experiment was started in 1914 at the request of Mr. Turing, then Collector of Kistna, as complaints had been received from certain cultivators that they suffered loss owing to their inability to transplant their crop early in the season.

In that year the planting was begun on the 15th of July and was continued at intervals of one week until eleven different transplantations had been done. A long term variety of paddy called *Konamani* was used.

It was obvious from the results that the later transplantations were unnecessary as the low yields obtained from those plots practically amounted to failure of the crop. The number of plantings in 1915 was therefore cut down to four at intervals of a fortnight and a shorter termed variety, *Sanna atragada*, experimented with. Planting began on July 11th. The results again showed a decrease in the case of the later transplantings.

In the following year, it was considered that some of the loss due to late planting might be made up, if the seedlings were planted closer together and if the land was manured. Accordingly the plots on which the two latest plantings were done were divided equally and one-half was manured with castor-cake at 200 lb. plus 100 lb. super per acre. At the same time it was thought desirable to test the effect of late planting on varieties of different length of term. Three varieties, *Rasangi* a short term, *Sanna atragada* a mid term and *Konamani* a long term paddy, were therefore experimented with. Planting began on the 7th July and was continued at intervals of a fortnight.

In 1917 the same arrangement was adopted as in 1916.

The results given below show conclusively that once the proper season for planting has been lost a decrease in yield is bound to follow:—

Year.	Planting.	Series.											
		1	2	3	4	5	6	7	8	9	10	11	Average.
1914-15.	First, July 15th.	4,449	4,721	4,113	4,295	4,129	2,316	4,763	4,959	5,231	3,339	3,568	3,935
	Second, July 22nd.	3,745	3,893	3,044	6,526	3,009	2,134	3,545	4,189	2,140	2,306	2,951	3,244
	Third, July 29th.	2,030	3,030	2,627	1,425	2,264	1,625	2,373	2,394	1,626	2,225	2,024	2,048
	Fourth, Aug. 5th.	1,960	1,494	1,720	1,653	1,708	1,485	2,212	1,836	1,053	1,829	1,898	1,734
	Fifth, Aug. 12th.	952	1,841	1,793	1,598	1,529	924	1,942	1,472	1,100	1,684	2,100	1,503
	Sixth, Aug. 19th.	978	1,521	1,386	1,186	1,164	826	1,535	1,064	762	1,402	2,045	1,265
	Seventh, Aug. 26th.	875	1,456	935	867	1,290	840	1,663	1,425	716	1,140	1,570	1,113
	Eighth, Sep. 2nd.	615	931	815	992	1,245	801	1,184	950	536	914	1,122	885

Year.	Planting.	Series.											
		1	2	3	4	5	6	7	8	9	10	11	Average.
1914-15—*cont.*	Ninth, Sep. 9th.	438	777	515	591	927	651	862	752	452	672	1,065	686
	Tenth, Sep. 16th.	289	783	534	464	918	488	668	603	314	421	927	546
	Eleventh, Sep. 23rd.	423	876	637	496	1,256	210	870	678	183	139	684	514

The yields of grain alone are given as the yields of straw varied for all practical purposes in the same way as the yields of grain. The total area under the first planting was three-quarters of an acre, under the second planting one acre and 40 cents in each of the other plantings.

Year.	Field number.	Area of plot.				First planting, July 11th.	Second planting, July 25th.	Third planting, Aug. 8th.	Fourth planting, Aug. 22nd.
1915-16.	19	12	12½	15	15	3,117 / 3,275	3,825 / 3,717	2,440 / 2,093	2,273 / 1,280
	20	10	15	15	15	3,440 / 3,230	3,467 / 3,347	2,867 / 2,480	2,700 / 1,667
	21	15	15	15	15	3,307 / 3,247	3,273 / 3,073	2,680 / 2,513	2,527 / 1,693
	28	10	10	10	10	4,970 / 5,940	3,240 / 2,940	2,920 / 2,310	2,260 / 1,870
	29	8½	8⅓	8⅓	8⅓	2,892 / 2,952	4,284 / 3,444	2,388 / 1,560	2,520 / 1,812

Year.	Variety.	Field number.	Area.	First planting, July 7th.	Second planting, July 21st.	Third planting, Aug. 4th.	Fourth planting, Aug. 18th. No manure.	Fourth planting, Aug. 18th. * Manure.	Fifth planting, Sep. 1st. No manure.	Fifth planting, Sep. 1st. * Manure.
1916-17.	Rasangi ...	10	10	2,750 / 2,940	2,650 / 2,760	2,080 / 3,160	1,980 / 3,440	2,020 / 3,600	1,740 / 3,060	1,760 / 3,100
		11	10	2,450 / 2,870	2,720 / 2,720	1,940 / 2,750	1,760 / 3,220	2,000 / 3,960	1,680 / 2,860	1,640 / 2,920
	Konamani...	13	10	2,335 / 5,980	1,610 / 4,740	1,450 / 3,800	1,480 / 3,660	1,480 / 3,650	1,660 / 3,280	1,860 / 3,460
		20	10	2,220 / 4,100	1,640 / 3,445	1,530 / 2,920	1,540 / 2,830	1,520 / 2,910	1,720 / 2,100	1,540 / 2,520
	Sanna atragada.	21	10	1,900 / 5,160	1,170 / 4,420	990 / 3,940	1,160 / 3,100	1,400 / 3,460	1,550 / 2,900	1,350 / 3,025
		22	10	2,180 / 4,580	1,220 / 3,830	820 / 3,320	1,040 / 3,140	1,300 / 3,520	1,250 / 2,800	1,475 / 3,225
		28	8	1,912 / 5,162	1,162 / 3,750	825 / 2,762	1,237 / 2,625	1,137 / 2,600	1,162 / 2,475	1,350 / 2,525
1917-18.	Rasangi ...	13	10	2,560 / 3,220	2,610 / 3,000	2,090 / 2,900	1,200 / 2,200	1,540 / 2,500	230 / 780	310 / 1,120
	Konamani ...	20	10	1,330 / 2,885	1,520 / 3,250	1,720 / 3,585	1,040 / 2,060	1,120 / 2,200	750 / 1,800	800 / 1,680
	Sanna atragada.	21	10	1,295 / 2,555	1,200 / 2,490	1,200 / 2,520	960 / 1,920	880 / 1,780	710 / 1,600	760 / 1,660
		22	10	1,370 / 2,590	1,430 / 2,620	1,370 / 2,710	1,100 / 2,500	1,000 / 2,210	880 / 2,240	700 / 1,600

* Castor cake at 200 lb. and super at 100 lb. per acre.

(*f*) *Early transplanting for the second crop.*—As stated above, the harvest of the first crop of paddy takes place in November-December and the transplanting of the second crop does not begin until February. There is thus an interval of two months during which no use is made of the water in the canal for paddy.

The object of this experiment was to try and discover a variety of paddy which could be transplanted immediately or shortly after the harvest of the first crop, which would mature in about the same time as the normal crop, i.e., about $3\frac{1}{2}$ months after transplanting and which would give as good a yield as that crop.

The advantages of having such a crop are obvious. A bigger area could be cropped and there would be practically no risk of there being a lack of water towards the end of the growing season, as sometimes happens.

The experiment proper did not begin until the second crop season of 1909–10. In February 1909, i.e., in the normal second crop season of 1908–09, a comparison of two local varieties, *Dalawa* and *Garikasannawari*, one Bengal variety, *Banku*, two varieties from Kurnool district, *Vankelu* and *Errabakkalu*, and one from Bellary district, *Mundlawari*, was made. The results of this test are included as they show the yield to be expected from the local varieties when transplanted in the normal season.

On the 8th November 1909 the two local varieties and the Bengal variety mentioned above were sown in seed-beds and a month later were transplanted. Until the favourable wind, the "*pairuyali*" or crop-wind from the south-east began to blow, the crops made little progress and both *Dalawa* and *Banku* suffered many casualties. Harvest occurred in the middle of April, that is the crop occupied the land about a month longer than would normally have been the case.

In 1910 *Banku*, *Garikasannawari*, *Dalawa* *Errabakkalu*, *Kadiri*, *Mundlawari* and *Vankelu* were tried. Sowing in this case was done on the 20th November and transplanting, as before, a month later. In this season, the evil effects of being grown out of season showed themselves in the seed-bed and after being transplanted only three varieties managed to survive. These were *Garikasannawari*, a local variety, *Kadiri* and *Errabakkalu*, two varieties from Kurnool district, which in their own locality are normally sown in December-January.

In the following year, *Errawadlu*, *Vellai Samba* and *Swarnawari* were added to the list of varieties under trial. Planting this year was done on the 3rd of January. *Garikasannawari*, *Dalawa*, *Errabakkalu* and *Vankelu* were the most successful, but none of them gave more than half a crop.

In 1912–13 and 1913-14 fifteen varieties were tried, of which among those not already mentioned *Bobbiliganti* and *Lambadikusuma* were the only two which gave any yield.

Year.	Field No.	Area of plot.	Variety.	Yield.
1909 ..	24	14	Dalawa	2,243/1,679
		10	Vankelu	1,050/1,450
		14	Errabakkalu ...	1,200/1,090
		8	Mundlawari	1,400/1,188
		18	Garikasannawari ..	2,178/2,006
		8	Banku .. .	1,937/2,750
1910 ...	28·29	26·52	Dalawa	569/430 ; 538/1,389
		9·8	Banku	155/444 ; 437/1,000
		25·50	Garikasannawari ...	1,876/3,200 2,142/5,600
1912 ...	26	24	Garikasannawari ...	1,553*
		3	Dalawa	1,133
		10	Errabakkalu ..	1,250
		3	Vankelu	1,166
1913 ..	26	14	Dalawa	1,548/2,078
1914 ...	24	20	Dalawa	600/3,650
		17	Bobbiliganti ...	1,488/5,000
		5	Lambadikusuma ...	1,124/4,000

* Yields of straw not quoted.

It will be seen from the above figures, i.e., from 1910 onwards that the endeavour to find a variety suited to the conditions was not successful. For the years for which no figures have been quoted, the results obtained were so miserable that it was not worthwhile going to the trouble of harvesting the plots separately.

The following quotation puts the matter clearly.* "The experience each year has been the same, either the plants have withered outright or they have rushed into head very quickly and in only a few cases has anything like a satisfactory yield been obtained, and then it has usually been a different variety each year. The season in this district for second crop paddy is evidently a definite one outside the limits of which no paddy will grow satisfactorily."

(4) *Method of planting*—(*g*) *Transplanting once or twice.*—This experiment was begun in 1909 and carried on for three years. In carrying out this experiment two plots in the same field were transplanted on the same date and 21 days later when the seedlings had become thoroughly established the crop in one plot was pulled out and re-transplanted.

The experiment was dropped as the results showed that there was nothing to be gained by the second transplanting which was of course an added expense to the cost of cultivation.

Year.	Area of plot.	Yield.	
		Twice transplanted.	Once transplanted.
1909 ..	30	2,928/3,136	2,651/4,466
1910 ..	35	1,560/2,048	1,862/2,368
1911 ...	22	2,950/3,625	3,059/3,795

* Annual Report, Samalkota Agricultural Station, for 1913–14, page 10.

(*h*) *Spacing.*—In the first year (1907) of this experiment, a comparison was made in three different fields, of planting several seedlings together in holes from 6 to 9 inches apart, with single seedlings planted approximately 9 inches apart. The experiment was of a tentative nature and the results here shown indicated that further investigation was desirable:—

Field.	Variety.	Area of plot.	Number of seedlings.	Yield.
13	Banku ...	30	Several	3,133
13	" ...	90	Single	2,567
15	" ...	16	Several	2,469
15	" ..	48	Single	2,698
18	Konamani ...	12·5	Several	2,776
18	" ...	12·5	Single	2,880

In 1908, the experiment proper was started. Four different fields and two varieties of paddy one long term, *Konamani*, and one short term, *Rasangi*, were experimented with. For three years the experiment was carried out in the same form, i.e., in each field a comparison was made between wide spacing and narrow spacing, the only difference from one year to the next being that the field used one year for the plots with single seedlings was used in the next for the plots with two seedlings per hole and vice versa. During these three years a direct comparison between single planting and double planting was not carried out in the same field. It was not until 1911 that this was done, in which year the plot with two seedlings per hole 4 inches apart was discontinued and a plot with 6 inches spacing introduced into both the singles and doubles series. In this year also the *Rasangi* plots were placed in two different fields.

During these four years the spacing of the seedlings was not done by actual measurement. Endeavours were made by close supervision and by using the same gang of coolies for each spacing, to have the planting carried out uniformly and at the desired distance, but these were not altogether successful. The results for these four years are tabulated below:—

Variety.	Field number.				Number of seedlings per hole.	Spacing.	Number of tillers per plant.			
	1908.	1909.	1910.	1911.			1908.	1909.	1910.	1911.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Konamani ...	20	19	20	19, 20	1	4′	1·4	3·0	2·3	2·4
	20	19	20	19, 20	1	6″		..	...	4·5
	20	19	20	19, 20	1	9″	2·8	6·0	5·6	7·1
	19	20	19	19, 20	2	4″	1·0	1·5	1·5	...
	19	20	19	19, 90	2	6″		...	...	4
	19	20	19	19, 20	2	9″	2·2	3·5	3·0	4
Rasangi ...	22	21	22	10, 10, 11	1	4″	1·6	2·0	2·0	2·4
	22	21	22	10, 10, 11	1	6″	...	...	...	3·5
	22	21	22	10, 10, 11	1	9″	4·0	6·0	4·0	6·3
	21	22	21	10. 10, 11	2	4″	1·1	1·0	1·5	...
	21	22	21	10, 10, 11	2	6″	...	..		3·4
	21	22	21	10, 10, 11	2	9″	1·6	2·5	2·7	3·9

Variety.	Field.			
	1908. (12)	1909. (13)	1910. (14)	1911. (15)
Konamani ...	2745/3449	2680/3120	2782/4474	2506/3524, 1810/2650
	...	..	...	2475/3281, 2290/2350
	2221/2404	2417/3550	2728/3980	2538/3769, 2220/2700
	2520/3640	2613/3200	2374/3962	... ...
	...	...	...	2088/3635, 1670/2950
	2406/2979	2310/3827	2292/3366	2338/3513, 2165/2140
Rasangi ...	2251/2096	2800/2636	2105/2232	2980/3960, 3540/4120, 3620/3655
	...	...	...	3020/2850, 3770/3840, 3255/3370
	1648/1429	2389/2145	1814/1952	2450/2600, 3870/4660, 3310/3825
	2169/1851	2620/2880	3520/3040	... ...
	..	...	..	3160/3450, 2680/5030, 3445/3370
	1769/1500	2986/2485	2315/2318	2930/2950, 2690/3630, 3455/3710

During 1908, 1909 and 1910 the plots were each about half an acre in extent, in 1911 the plots were each 10 cents in field No. 10, 20 cents in field Nos. 11 and 20 and 16 cents in field No. 19.

2-A

From 1912 onwards, spacing was done by actual measurement and from that year a greater number of plots under each method were laid down in order to increase the accuracy of the results obtained. From 1913 the plots planted with two seedlings per hole were discontinued and from the same year an attempt was made to gauge the effect of manure on the yields from the various spaced plots. The treatment and arrangement of the plots are shown in the table of results given below:—

Year.	Variety.	Area of plot.	Number of seedlings.	Spacing.	Number of tillers per plant.	Yield. Field No. 10.	Yield. Field No. 11.
1912	Rasangi.	20	Single seedling.	4″	1·8	4,960 / 5,200	3,625 / 5,230
		20		6″	3·8	4,665 / 4,695	4,145 / 7,300
		20		9″	9·2	4,510 / 4,340	4,540 / 7,700
		20	Two seedlings.	6″	2·2	4,398 / 5,690	4,070 / 7,000
		20		9″	4·7	4,780 / 5,630	4,100 / 6,140
						Field No. 17.	Field No. 18.
	Konamani.	16⅔	Single seedling.	4″	1·9	3,423 / 5,880	3,381 / 5,226
		16⅔		6″	4·0	4,443 / 3,060	4,095 / 5,070
		16⅔		9″	7·6	4,053 / 5,820	3,885 / 4,860
		16⅔	Two seedlings.	6″	2·3	3.501 / 5,220	3,381 / 6,060
		16⅔		9″	4·5	3,501 / 5,130	3,669 / 5,232

Year.	Variety.	Area of plot.	Number of seedlings.	Spacing.	Number of tillers per plant.	Yield. Field No. 10.	Yield. Field No. 11 (1).
1913	Rasangi.	12½	Single seedling.	4″	2·0	3,760 / 3,208	...
		6¼		"	2·1	4,012 / 3,600	...
		10		"	1·9	...	3,540 / 4,090
		10		"	2·0	...	3,544 / 4,910
		12½		6″	4·0	3,954 / 3,304	...
		6¼		"	3·3	3,022 / 2,320	...
		10		"	4·2	...	4,040 / 5'170
		10		"	4·3	...	4,071 / 5,170
		12½		9″	8·5	3,307 / 2,496	...
		12½		"	7·9	3,340 / 3,000	...
		10		"	8·7	...	3,700 / 4,390
		10		"	7·6	...	3,965 / 4,580
						Field No. 17. (1).	Field No. 18.
	Konamani.	8½	Single seedling.	4″	2·4	3,396 / 6,636	...
		8½		"	2·1	3,396 / 7,188	...
		8½		"	2·0	...	3,180 / 3,816
		8½		"	2·2	...	2,832 / 4,080
		8½		6″	4·4	3,612 / 6,624	...
		8½		"	4·5	3,648 / 6,792	...
		8½		"	3·6	...	3,096 / 3,720
		8½		"	4·2	...	3,600 / 4,056
		8½		9″	9·5	4,044 / 6,720	...
		8½		"	8·9	3,792 / 5,952	...
		8½		"	7·7	...	3,156 / 3,732
		8½		"	7·9	...	3,588 / 4,092

Year.	Variety.	Area of plot.	No. of seedlings.	Spacing.	No. of tillers per plant.	Yield.			
						Field No. 10.		Field No. 11 (1).	
1914	Rasangi.	One-sixth.	Single seedling.	4″	1·8 ; 1·8	4,118/3,936		3,395/3,382	
1914	Rasangi.	,,	Single seedling.	6″	4·1 ; 4·0	3,614/4,056		3,228/3,266	
1914	Rasangi.	,,	Single seedling.	9″	8·5 ; 7·5	3,823/3,580		3,108/3,238	
						Field No. 17 (1).		Field No. 18.	
1914	Konamani.	One-sixth.	Single seedling.	4″	1·5 ; 1·6	3,193/4,187		3,109/4,793	
1914	Konamani.	,,	Single seedling.	6″	3·1 ; 3·2	3,375/3,962		3,353/4,300	
1914	Konamani.	,,	Single seedling.	9″	8·2 ; 7·6	3,355/4,402		3,394/3,347	
						Field No. 10.		Field No. 11 (1).	
1915	Rasangi.	One-sixth.	Single seedling.	4″	1·5 ; 1·8	4,513/5,882		3,940/5,511	
1915	Rasangi.	,,	Single seedling.	6″	3·3 ; 3·9	4,792/6,292		4,265/5,531	
1915	Rasangi.	,,	Single seedling.	9″	7·4 ; 7·5	4,679/5,409		4,452/5,163	
						Field No. 13.		Field No. 14.	
						Un-manured.	Manured.	Un-manured.	Manured.
1915	Konamani.	One-sixth.	Single seedling.	4″	1·9 ; 1·8	3,057/4,502	2,896/4,672	2,902/3,740	...
1915	Konamani.	,,	Single seedling.		1·7 ; 1·7	...	...	...	3,064/4,436
1915	Konamani.	,,	Single seedling.	6″	3·7 ; 3·8	3,309/4,108	3,008/4,194	...	
1915	Konamani.	,,	Single seedling.		3·2 ; 3·6	...	...	3,038/3,610	3,179/3,954
1915	Konamani.	,,	Single seedling.	9″	7·9 ; 8·0	3,325/4,210	3,147/4,038	...	...
1915	Konamani.	,,	Single seedling.		7·5 ; 7·7	...	...	2,785/3,128	3,036/3,817

(1) The whole field was manured with green manure and super (1 cwt. per acre).

In 1914 the plots were scattered uniformly over the fields. In fields Nos. 19 and 11 there were 32 plots under each method. In field No. 17 the 9″ plot was repeated 37 times and the others each 38 times ; in field No. 18, the 6″ plot was repeated 38 and the other 37 times.

In 1915 there were 24 plots under each method in each of the fields Nos. 10 and 11. In field No. 13 there were eighteen 4″, eighteen 6″ and fifteen 9″ plots in each half of the field and in field No. 14 there were 15 plots for each spacing in the manured half of the field and seventeen 4″ and fourteen

9″ plots in the unmanured half. The figures quoted above are the average figures.

The first conclusion arrived at after three years of experiment was that planting two seedlings per hole 4″ apart was distinctly uneconomical. That plot was therefore discontinued. Two years later the same fate befell the other two plots with two seedlings per hole spaced respectively 6″ and 9″ apart. There is no doubt that in this heavy delta land, with the small loss that occurs if planting takes place at the right time, it is sheer waste to plant more than one seedling per hole.

As regards the single plantings, it is fairly obvious that as far as *Konamani* is concerned the manuring had little effect on the crop. It is, however, apparent that after the first two years the widest spacing was more suited to the long term variety *Konamani* than was the closest spacing. With the short term variety *Rasangi* the case is rather different. During the first four years the results were in favour of the closer planting for this variety. From 1912 there is a noticeable difference between the results obtained from the two fields Nos. 10 and 11. In the case of field No. 10 the results favoured the closest spacing, whereas in the case of field No. 11 the results inclined in the opposite direction, in favour of wider spacing.

The conclusion arrived at from these results and from the crop notes taken while the crop was growing is that no definite law can be laid down as to what is the correct spacing to be adopted in each case. Each man will have to work this out for himself, suiting his distance according to the variety he grows, the fertility of his land and his command of labour at harvesting time. With a long term or wide spreading variety he will plant further apart than with a short term or erect variety, on more fertile land he will plant further apart than on less fertile land as in the former case the crop will tiller better and will require more room and by planting closer or further apart he can hasten or delay by a short time the date of maturity and so extend the period of harvesting.

THE ECONOMIC TRANSPLANTING OF PADDY *(ORYZA SATIVA)*.

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The paddy crop in Madras is almost universally transplanted, and in this process it is almost as universal to find a number of seedlings planted in a bunch. In many cases, the number is almost incredible: one of the writers has notes of a village near Trichinopoly, where in two successive seasons, more than fifty seedlings to the bunch were found. Even though this may be an exceptional case, there is no doubt that the loss in seed is in the aggregate enormous; in the single district of Tanjore, the most important paddy growing district in Madras, it has been calculated that the saving in seed which would be effected by transplanting paddy seedlings separately, would be enough to feed the whole of the district for three weeks every year, apart altogether from any increase in the crop which might result.

Accordingly we find that the question of the most economical number of seedlings, and the best distance at which to plant them, has figured largely in the experimental work of the department for some years. Mr. Benson, who was then Deputy Director, as early as 1900, wrote a note[1] for the Tanjore Agricultural Association, in which he called attention to the waste in seedlings that commonly occurred, and the results that followed, emphasising not only the waste of seed, but the consequent weakening of the crop.

These problems have also received attention in other parts of India,[2] where paddy is an important crop, and in the Philippines[3] a good deal of careful work along these lines has been done by Jacobson.

The fact that the methods[4] usually adopted were susceptible of considerable improvement, was indeed so patent, that for a long time the recommendation to plant economically has been one of the leading lines of the Madras Department's demonstrational activities, and the cry of 'single seedling' has reached practically every district.

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[1] D. Dis. 1912, dated 13th December 1904.

[2] See Annual Reports of Bengal, reports of the Cuttack and Sabour Agricultural Stations: also "Some observations on Upper Burma Paddy": E. Thompstone (Agricultural Journal of India, Vol. X, page 26).

[3] Observations on the influence of area per plant on yield of grain in rice culture. H. C. Jacobson: Philippine Agricultural Review: Vol. VIII, page 252.

[4] In a part of the Kistna district of Madras Presidency, it is the custom to plant seedlings singly. It is not known why this particular tract has adopted the practice and so far as the writers know, it is unique in this respect.

Meanwhile careful experiments were initiated at Samalkota in 1908, and at Coimbatore in 1910, to ascertain with some degree of accuracy, just what spacing should be adopted, and just what is the smallest number of seedlings that can be relied on to give a full crop.

These two points cannot be considered entirely by themselves, as they are largely bound up with the age and healthiness of the seedlings, and the fertility of the land. In considering the results given in this paper, it must be remembered that the seedlings were in most cases grown in a seed-bed sown at a rather lower rate than is customary, and that they were in consequence, larger and stouter than those usually available. The question of manuring and its effect on spacing formed the subject of a separate group ef experiments. It will be convenient to consider the experiments at the two stations separately.

COIMBATORE.

The experiments were carried out on plots averaging 16 cents each, and were laid out in two series, each series being planted in alternate years with one or other of the two most important local paddies. These differed rather in their habits: *Sadai Samba*, being on the coarse side, a heavy yielder and ripening ten to fourteen days before the other, *Sinna Samba*—a finer paddy with a smaller grain and a rather lower average yield. The full yields for the eight years will be found in Table I.

TABLE I.

Yields in pounds per acre.

Methods of planting.	1910–11.		1911–12.		1912–13.		1913–14.		1914–15.		1915–16.		1916–17.		1917–18.		Average.	
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
Sadai Samba.																		
Locals ...	3,919	4,046	2,594	3,553	2,900	4,175	2,502	3,602	3,188	8,060	2,917	3,773	3,914	5,164	3,346	6,327	**3,160**	**4,838**
Singles 4″ ...	3,911	3,993	2,410	2,880	2,902	3,308	3,477	4,212	2,938	4,079	3,042	3,517	3,753	5,086	2,496	4,559	**3,116**	**3,954**
,, 6″ ...	4,175	4,359	3,148	3,897	3,159	3,592	3,188	3,741	3,155	6,243	2,492	2,423	3,879	4,260	1,971	4,500	**3,146**	**4,127**
,, 9″ ...	2,724	2,146	3,229	5,155	2,593	4,040	2,205	3,210	3,194	5,700	2,575	2,655	4,217	5,289	2,127	3,373	**2,867**	**3,946**
Doubles 9″ ...	2,629	2,787	3,119	4,068	3,434	3,792	3,232	4,154	3,994	6,446	2,541	2,523	4,112	5,034	2,977	4,217	**3,255**	**4,128**
Trebles 9″ ...	2,496	2,189	2,862	3,262	2,677	3,250	3,279	4,205	4,459	6,650	1,970	2,100	4,353	5,735	2,819	5,669	**3,202**	**4,133**
,, 12″ ...	4,586	4,138	3,309	4,177	2,445	2,751	3,593	4,203	4,735	5,566	2,574	3,360	3,709	4,465	2,962	3,703	**3,489**	**4,045**
Sinna Samba.																		
Locals ...	2,130	2,800	2,713	6,161	2,460	4,070	2,969	4,842	2,796	5,661	2,849	3,641	2,698	5,364	3,400	4,873	**2,752**	**4,677**
Singles 4″ ...	3,064	3,742	3,250	6,973	2,482	4,400	2,666	3,908	2,677	4,831	2,461	3,258	2,396	4,453	3,186	5,358	**3,773**	**4,615**
,, 6″ ...	2,907	3,381	3,418	5,442	2,200	3,540	3,062	5,025	3,058	5,487	3,413	4,902	3,566	6,450	3,883	5,518	**3,188**	**4,968**
,, 9″ ...	2,762	3,350	3,476	5,943	2,709	4,335	3,197	4,407	2,812	4,588	2,877	3,527	2,605	4,605	3,079	4,683	**2,940**	**4,430**
Doubles 9″ ...	2,215	2,923	3,099	4,583	2,773	4,783	3,581	5,860	2,565	4,510	2,650	3,150	2,673	6,505	3,696	6,949	**2,907**	**4,908**
Trebles 9″ ...	2,531	2,442	2,905	3,729	2,813	4,542	3,297	4,150	3,226	6,452	3,127	3,516	2,619	5,429	2,710	5,408	**2,904**	**4,459**
,, 12″ ...	2,200	2,211	2,610	4,016	2,338	3,815	2,947	4,687	3,175	5,072	2,988	3,744	2,976	5,952	3,000	4,691	**2,779**	**4,274**

The plots lie on either side of an irrigation channel running from the tank or reservoir from which the irrigation supply was obtained: the lower numbers were nearer the source and the higher numbers further away. It was found by comparing the yield of a permanently unmanured plot near the source, with that from a similar plot at the extreme end of the series, that there was a considerable reduction in fertility in the land in the distant plot, amounting to a difference of something over 20 per cent.* This was considered to be the result of the silt in the irrigation water, which was naturally greatest near the tank, and the further assumption was made that the deterioration was in direct ratio to the distance from the tank. The various plantings in different plots were accordingly so arranged, that the totals of the numbers of the plots occupied by each planting should add up to approximately the same figure, thus eliminating as far as was possible the effect of this variation. A glance at Table II will make this plain.

* Per cent of average.

	Grain.	Straw.
Plot nearest tank.	111·8	111·4
Plot farthest from tank ...	88·2	88·6

TABLE II.

Methods of planting.	Sadai Samba.								
	Plot occupied in								Total.
	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
Locals	11	14	7	18	3	6	17	6	82
Singles 4"	9	16	3	12	19	8	7	10	84
" 6"	13	4	9	14	5	10	13	16	84
" 9"	15	6	11	16	7	12	5	12	84
Doubles 9"	17	8	13	4	9	14	11	8	84
Trebles 9"	19	10	15	6	11	16	3	4	84
" 12"	1	12	17	8	13	4	15	14	84

PLATE I.

Methods of planting.	Sinna Samba.								
	Plot occupied in								Total.
	1910. (10)	1911. (11)	1912. (12)	1913. (13)	1914. (14)	1915. (15)	1916. (16)	1917. (17)	
Locals	16	1	12	3	8	13	10	17	80
Singles 4″	4	5	14	1	10	17	16	13	80
,, 6″	6	11	16	7	12	3	8	7	70
,, 9″	7	13	4	9	14	5	14	15	81
Doubles 9″	10	15	6	11	16	7	6	9	80
Trebles 9″	12	17	8	13	4	9	12	5	80
,, 12″	14	19	10	15	6	11	4	1	80

It was found also that the western strip was slightly more fertile than the eastern strip: but as the varieties changed sides each year, this does not affect the results.

The manuring of the plots was superior to local practice, without being in any way excessive:—

1910. Wild indigo (*Tephrosia purpurea*): grown in the plot: made up to 4,000 lb. with added leaf, where necessary.

1911. Wild indigo, plus 5 cwt. of fish manure.

1912. Wild indigo (about 4,000 lb.).

1913. Nil.

1914. Nil.

1915. Nil.

1916. 500 lb. castor cake.

1917. 400 lb. fish guano.[1]

Plate I shows the methods adopted at this station to ensure accurate spacing; subsequent counts showed that a high degree of accuracy was obtained.

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[1] The name given to broken fish from which the oil has been removed a local product.

Owing to the variation in the plots, only the averages of all the yields can be compared, and in the next table, number III, the average yields from all the plots for the whole series of years, and for both the varieties, are shown worked out as percentages of the yield from 'locals.'

TABLE III.

Methods of planting.	Sadai Samba.		Sinna Samba.	
	Grain.	Straw.	Grain.	Straw.
Locals	100·0	100·0	100·0	100·0
Singles 4″	98·6	81·7	100·7	98·6
„ 6″	99·5	85·3	115·8	106·2
„ 9″	90·7	81·5	106·7	94·7
Doubles 9″	103·0	85·3	105·5	104·9
Trebles 9″	101·3	85·4	105·4	95·3
„ 12″	110·4	83·6	100·9	91·3

We may first remark that the yields shown against 'locals,' are almost certainly too high, in that they do not really represent the yields that would have been obtained from a crop planted out strictly in accordance with local practice, i.e., with very small seedlings from a crowded seed-bed, transplanted in bunches of anything up to 15 in a bunch. In the first place, the women, who do all the work of planting, very soon became so used to planting thinly, that they found it difficult to go back to the old method, and secondly, our seedlings were generally so much larger than those to which they were accustomed, that it was impossible to plant very many at a time.

As the figures stand, and taking first those relating to the *Sadai Samba* crop, all the 'singles' are below the yield from 'locals'; slightly in the yield of grain and markedly in the yield of straw. The 'doubles' and two 'trebles' are both superior in their yields of grain, but still inferior in straw production. When the figures for the *Sinna Samba* crop are considered, a different result is seen. All the economically spaced plots have beaten the 'local' in point of yield of grain, and two of them in point of straw. Evidently this crop, from its slower growth or other characteristic, is more able to take advantage of the greater space afforded it.

The optimum spacing of those tested is, in the case of *Sadai Samba*, seen to be 12 inches, with three seedlings put in at each hole. Why this should be so, it is not easy to see, but one point must be mentioned and that is the risk of casualties. Crabs especially, in Madras, do much damage to young seedlings, and if the plants are put out singly, a casualty will leave a blank, and probably implies a much greater loss than that occasioned by planting two seedlings which will compete with each other for room. That this theory must not be pushed too far, is shown by the fact that 'trebles 9 inches' is in no way better, in fact it is rather worse, than 'doubles 9 inches' though the latter is distinctly superior to "singles 9 inches." The best spacing for single planting lies evidently somewhere between 4″ and 9″ : 6″ giving a higher yield than either of these, in both grain and straw. With *Sinna Samba* the figures are capable of more easy explanation. Again 6″ spacing with singles is better than either 4″ or 9″, though a reference to Table II shows it has been rather favourably situated: beyond this last distance, increasing the number of seedlings does not make up for the extra space, and the yield steadily drops. The straw figures are a little confusing: with both varieties the 6″ single spacing gives more straw than either of the other two 'singles.' Doubling the seedlings at the greater distance gives in both cases an increase; trebling them makes no difference to *Sadai Samba*, but heavily reduces the yield in *Sinna Samba.*

SAMALKOTA.

Here the land is alluvial in nature, of comparatively high fertility, and irrigated from a canal taking off from the Godavari river. Definite plots were not allotted to the experiment as at Coimbatore, but fresh land was occasionally taken up. As the fields are fairly large, it was possible to lay out more than one plot in a single field. The results obtained year by year are thus of more interest than those at Coimbatore, where only the full averages represent the real value.

The experiments were not so continuous as at Coimbatore: certain spacings were continued right through, while others were modified. Two varieties were used: *Rasangi*, corresponding to *Sadai Samba*, a comparatively quick growing coarse variety, and *Konamani*, like *Sinna Samba*, a longer term paddy of better quality.

The full results are given below:—

TABLE IV.

Methods of planting.	1908–09.		1909–10.		1910–11.		1911–12.		1912–13.	
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
Rasangi.										
Singles 4″ ...	2251	2096	2800	2636	2105	2232	3440	3848	4293	5215
„ 6″ ...	...	...	...	...	...	...	3325	3388	4405	5998
„ 9″ ...	1648	1429	2389	2145	1814	1952	3235	3728	4525	6020
Doubles 4″ ...	2169	1851	2620	2880	2520	3045	...	...	...	...
„ 6″ ...	...	...	...	...	...	...	3182	3805	4234	6345
„ 9″ ...	1769	1500	2986	2485	2496	2318	4133	3500	4440	5885
Konamani.										
Singles 4″ ...	2745	3449	2680	3120	2782	4474	2119	3069	3402	5553
„ 6″ ...	...	...	...	...	...	...	2372	2764	4269	4065
„ 9″ ...	2221	2404	2417	3550	2728	3980	2361	3153	3969	5340
Doubles 4″ ...	2520	3640	2613	3213	2374	3962	...	...	...	...
„ 6″ ...	...	...	...	...	...	...	1855	3250	3441	5640
„ 9″ ...	2406	2979	2310	3827	2292	3366	2241	2750	3585	5181

Methods of planting.	1913–14.				1914–15.				1915–16.			
	Unmanured.		Manured.		Unmanured.		Manured.		Unmanured.		Manured.	
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
Rasangi.												
Singles 4″ ...	3886	3404	3542	4500	4118	3936	3395	3382	4513	5882	3940	5511
„ 6″ ...	3489	2812	4056	5170	3614	4056	3228	3266	4792	6292	4265	5531
„ 9″ ...	3324	2748	3833	4485	3823	3580	3108	3238	4679	5409	4452	5163
Doubles 4″ ...	...	...	...	...		...	...	...	...	...	...	...
„ 6″ ...		...	...	...	...	...	...	...	...	.	...	...
„ 9″ ...	...	...		...	...		...	...	...	...	...	...
Konamani.												
Singles 4″ ...	2970	3948	3396	6912	3109	4793	3193	4187	2980	4121	2980	4554
„ 6″ ...	3348	3888	3630	6708	3353	4300	3375	3962	3174	3859	3094	4074
„ 9″ ...	3372	3912	3918	6336	3394	3947	3355	4402	3055	3669	3092	3928
Doubles 4″ ...	...	...	...	...	...	...	...	...		...	...	...
„ 6″ ...	...	...	...	...	...	...	...	...	...	...	...	...
„ 9″ ...	...	...		...	...	...	...	...	.	...	...	...

Yields in pounds per acre.

These figures may be best considered by taking them in series, and owing to seasonal variation, the comparisons can only be drawn from the results of the same season, or set of seasons. We will begin with the three years results of 'singles' and 'doubles' at 4″ and 9″ respectively. For ease in comparison, we have taken the average yield of all the plots concerned as *par*, and shown the result from each spacing as a proportionate percentage. Taking the average for the three years 1908 to 1910, and the five years 1908 to 1912, we get the figures below:—

TABLE V.

Methods of planting.	Average for three years.		Average for five years.	
	Grain.	Straw.	Grain.	Straw.
Rasangi.				
Singles 4″	104·3	106·4	104·5	106·5
" 9″	84·6	83·1	92·2	94·0
Doubles 4″	106·9	116·3	...	...
" 9″	104·2	94·1	103·2	99·4
Konamani.				
Singles 4″	109·1	105·0	103·0	105·2
" 9″	97·8	93·8	101·5	97·9
Doubles 4″	99·8	103·6	...	...
" 9″	93·2	97·5	95·5	96·9

The figures are gratifyingly simple, and show that the wider spacing is in all cases too wide, though the reduction due to the 9″ spacing is less in the case of *Konamani* than in *Rasangi*. If two seedlings are used instead of one, an increase is obtained, in *Rasangi*, though not in *Konamani*. It may be that the more slowly growing variety produces more tillers, and can give a full crop, if singles only are planted.

The next table introduces a 6″ planting both 'singles' and 'doubles,' and comparative figures are available for two years.

TABLE VI.

Rasangi. Methods of planting.	Grain.	Straw.	*Konamani.* Methods of planting.	Grain.	Straw.
Singles 4″ ...	101·7	96·6	Singles 4″ ...	93·9	105·1
" 6″ ...	101·2	97·2	" 6″ ...	111·3	85·5
" 9″ ...	101·2	102·1	" 9″ ...	107·1	104·4
Doubles 6″ ...	97·1	105·9	Doubles 6″ ...	88·5	108·9
" 9″ ...	98·7	97·8	" 9″ ...	99·2	96·1

This period is apparently not long enough to give reliable figures, as the results are at variance with those obtained from longer series: in the case of *Rasangi* heavier straw is obtained from 'singles 9″' than 'singles 6″', and this again is better than 'singles 4″'; a result not borne out by experience elsewhere. It was noted that in one year the '4″ single' plot was badly lodged, and this has reduced the yield of this plot. The *Konamani* figures too are not very clear, but 6″ seems to be about the right distance to plant, and it is not necessary to use two seedlings.

In the next table, single planting is compared, for three spacings for five years, and for two spacings for eight years, the full term of the experiment:—

TABLE VII.

Methods of planting.	Average for five years.		Average for eight years.	
	Grain.	Straw.	Grain.	Straw.
Rasangi.				
Singles 4″	102·6	102·5	105·1	106·2
" 6″	98·8	100·7	...	...
" 9″	98·5	96·8	94·9	93·8
Konamani.				
Singles 4″	92·8	106·2	98·9	104·2
" 6″	104·6	94·3	...	...
" 9″	102·6	99·5	101·0	95·8

These figures are most conclusive, and need little comment. 'Singles 4″' is the best of the spacings tried for *Rasangi*, though it is not necessarily the absolute best (this may be at a still closer rate), and this conclusion holds good for both grain and straw. In the case of *Konamani* it is clear that the *optimum* spacing lies somewhere between 4″ and 9″ for the grain, though for straw it is necessary to plant closer.

It was mentioned above, that the correct spacing was closely bound up with the fertility of the land, and for the last three years of the experiment, the different plantings were duplicated on manured and unmanured land in order to test this question. Where manure is applied, the wider spacings are proportionately better in practically all cases, the only exception being the yield of straw from the longer growing variety.

TABLE VIII.

Methods of planting.	Average for three years.			
	Unmanured.		Manured.	
	Grain.	Straw.	Grain.	Straw.
Rasangi.				
Singles 4″	104·2	105·4	96·9	100
" 6″	98·1	102·2	102·3	103·7
" 9″	97·6	92·3	100·5	96·2
Konamani.				
Singles 4″	94·5	105·7	95·7	104·3
" 6″	103·1	99·2	100·9	97·6
" 9″	102·4	95·1	103·3	98·1

The *optimum* spacing for *Rasangi* is seen to be on fertile or manured land, not 4″ but 6″—while similarly, for *Konamani* the *optimum* is now nearer 9″ than 6″.

General conclusions.

The experiments are conclusive in showing that a very considerable reduction can be obtained by greater care in planting out the seedlings. Local practice varies very much, the rate of sowing in the seed-bed being from 350 lb. up to 750 lb. an acre. The ratio of seed-bed to area planted varies widely from as low as 1 : 5 up to 1 : 12. Taking the extremes in both cases, we may say that the average seed-rate per planted acre is from 30 lb. to 150 lb. A field planted singly at 4″, i.e., with 16 square inches to each plant, should need theoretically about 400,000 seedlings, a number which except in the coarsest varieties, could probably be obtained from not more than 20 lb. Indeed, the standard recommended by the department, on the initiative we believe, of Mr. Sampson, is 7 Madras measures in 7 cents for each acre to be planted : this means a seed-rate of about 280 lb. in the seed-bed, a ratio of 1 : 14 and a rate for the planted area of rather less than 20 lb. per acre[1].

This is, as said above, if the seedlings are given an area of 16 square inches each. There is no doubt, from the figures already given that this area, in many cases, could be exceeded with safety. The conclusion drawn from the Philippine experiments[2], referred to above, is that single seedlings will usually not produce maximum yields if given more space than 100 square centimetres (equivalent to singles 3·9″). Thompstone[2] also found that spacing for single plants above 16 square inches,

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[1] Jacobson recommends 760 lb. to the acre in the seed-bed ; a ratio of 1 to 20, and a rate for the planted area of 38 lb. (The rate of sowing nursery beds, etc.—Philippine Agricultural Review, Vol. VIII, page 273.)

[2] Loc. cit.

reduced the yield. It is fortunate that in both the Madras experiments, two varieties differing considerably in their duration of growth were used, as it has been possible clearly to show that different varieties behave very differently in the different spacings. It is evident, and Philippine experience partially corroborates the fact, that late maturing varieties should be given more room than early maturing varieties. It is not altogether a question of tillering, as counts were made at Samalkota of the flowering culms, of each variety, and in each of two spacings, and are given in the subjoined table :—

TABLE IX.

Methods of planting.	Tillers per plant.						
	1908–09.	1909–10.	1910–11.	1911–12.	1912–13.	1913–14.	1914–15.
Rasangi.							
Singles 4″	1·6	2·0	2·0	2·4	1·8	2·1	1·8
„ 9″	4·0	6·0	4·0	6·3	9·2	8·2	8·5
Konamani.							
Singles 4″	1·4	3·0	2·3	2·4	1·9	2·1	1·6
„ 9″	2·8	6·0	5·6	7·1	7·6	7·8	7·6

It is obvious that an increase in area, leads to an increase in the number of tillers, when a single variety is under consideration, but it is clear also that the number of tillers is not a definite factor of the yield, and this again corroborates Jacobson's results in the Philippine's and Thompstone's work in Burma. A point of some interest, which does not seem yet to have received attention, is that continuous selection of seed from widely spaced plants, should work towards the elimination of weak tillering plants, and to the establishment of a strain in which this feature is strongly marked.

The experiments have also proved that the higher the fertility, whether natural or added, the greater the space which the seedlings can profitably occupy. The question of the number of seedlings which should be planted in a hill is not quite so clear. Sethi at Cuttack[1] reports as a result of nine years' comparison on duplicate plots, practically no difference between, 1, 2, 4 or 8 seedlings a hole. He does not unfortunately state the distance the holes were apart. Thompstone[2] states that in group planting, it was found that though the best yields were obtained by planting doubles, the average number of shoots arising from each pit varied as the number of transplants but not in direct proportion : he gives no details of the experiment. Jacobson[2] emphasises the risk of casualties incurred when singles are planted, but notes that overcrowding results when the hills are too close. He recommends 3 to 5 seedlings. There would thus appear to be little difference between planting single seedlings closely or doubles or trebles more widely. As indicated above, the risk of casualties varies in different conditions. The general trend of these experiments is against doubles, and in favour of singles, but the striking success of the trebles 12″ at Coimbatore must be recognized : this gives a spacing equal to singles 7″.

Finally there is the question of the straw. In most of the experiments reported, there is a

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[1] Report on the Agricultural activities of Government in Bihar and Orissa for the year 1915-16, page 58.

[2] Loc. cit.

distinct drop in the yield of straw, with the more thinly planted plots. When this is accompanied, as it may be, by an increase in grain, it is obviously a step in the right direction, since there is in most cases far more straw produced than can be eaten by the cattle requisite for cultivation purposes.

SUMMARY.

1. The saving of seed by planting out paddy seedlings economically may be very large.

2. Such economical planting not only saves seed but will, if the correct spacing is adopted, bring about an increase in the yield of grain, accompanied by a decrease in the straw.

3. The correct spacing has been shown to depend upon—

   (*a*) The variety of paddy.
   (*b*) The fertility of the land.

GREEN LEAF MANURING OF DRY PADDY LAND.

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When bulky manures, such as green leaf, are puddled into paddy land a large amount of debris floats on the water during later ploughings and waterings. At Coimbatore the south-west monsoon wind blows this into one corner of each plot and a considerable accumulation may occur. This results in unsightly patches of coarse growth in the crop. Removal of the debris reduces but does not altogether prevent this.

In experimental work these corners are a nuisance as they increase the area that must be rejected as outskirts, a matter of some importance in small plots. It was thought that ploughing in the green leaf after harvest, thus giving it time to decompose to a large extent before puddling for the next crop, might be more satisfactory.

Another point of interest is involved in manuring in this way. Dr. Harrison has shown that much of the nitrogen of green leaf, when the latter decomposes in puddle conditions, passes off as gas and is lost. It appeared possible that this loss of nitrogen might be prevented, and the manurial value of the green leaf increased, by ploughing the latter into the dry land after harvest.

A trial was made on a block of twelve plots of which six were manured dry and six by puddling, the rate of application in each case being 5,000 lb. of *Calotropis* leaf per acre. Before the dry manuring, which was done in February, a light irrigation was given to moisten the soil as it had been allowed to get too hard to work well. An iron plough, the 'Monsoon', was used and the leaf was applied in the furrow and well covered. By August the bulk of it had rotted so as to lose all form. The puddle manuring was done in the ordinary way in August whilst preparing the land for planting.

All the plots, which measured 40′ × 40′ after cutting off outskirts, were similarly planted and uniformly treated afterwards. There was no marked difference in the growth of the crop but shortly before harvest the dry manured plots looked rather a lighter crop, were all distinctly greener than the others and did not ripen off so quickly.

The yields of the separate plots, together with the totals, are given in the following statement, where also the arrangement of the plots is shown.

Green leaf *puddled before planting* versus *ploughed in dry after previous crop* : yields, in lb., of plots 40′×40′

1. Dry	107	7. Puddled	98·5
2. Puddled	87·5	8. Dry	86·5
3. Dry	70	9. Puddled	95·5
4. Puddled	81	10. Dry	71
5. Dry	58·5	11. Puddled	84
6. Puddled	73	12. Dry	73·5

	Dry.	Puddled.
Totals ...	466·5	519·5

Plot No. 1 was near the channel and through it the whole block was irrigated. This very probably accounts for its giving the highest yield of the lot. In spite of this the total of the puddled plots is over 11 per cent more than the dry; moreover the plots taken separately bear out this superiority.

It is, of course, impossible to rely on an isolated experiment of this kind, but the odds are distinctly in favour of puddling the green manure before planting and the figures are simply given as a record of this fact in this particular case.

FLOODING AND FURROW IRRIGATION IN COIMBATORE.

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AND
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In the Coimbatore district, where a considerable area of land is highly farmed under irrigation, by well water, lifted often from great depths, the question of economy in the application of this water is of the first importance. Not only does a saving of water imply a reduction in the cost of production, but it means that the supply from a given well can be made to go further, and command a larger area.

From the start, this question has engaged the attention of the Central Agricultural Station, and the annual reports from 1908 to 1911 contain the records of numerous isolated experiments on the irrigation of the crop by water applied in furrows, instead of the more usual (though not universal) system of flooding the land in beds. At first sight, it would seem on theoretical grounds, that such furrow irrigation would show a considerable economy over the method of surface flooding, a method which not only exposes the water to the maximum loss from evaporation, but leaves the soil in an unhealthy physical condition. The usual method of irrigation is to lay the land out into beds or checks of about 15 links square, surrounded by small ridges, to keep in the water. Small irrigation channels about 1½ feet broad and 6 inches deep are run between two rows of beds and water is turned into the beds in sequence. The method adopted for furrow irrigation was to make furrows about 1½ feet wide by means of a Planet Jr. Hoe, before planting, in planted crops, and, either before sowing, or after the plants had grown up to about 9 inches high, in the case of sown crops. They were laid out as far as possible, level from end to end.

The results obtained from these experiments were difficult to interpret and showed most diverse results ; at one time the ridge plots and at another the bed plots proved superior. It was realized that much more care in selecting the plots and carrying out the experiments was necessary if any definite results were to be obtained.

Accordingly in 1910 in each of two fields No. 18 and No. 20, a series of four plots was permanently laid out and demarcated with stones. The plots were arranged in the form of a square, each being 25 cents in area, and they were always treated in duplicate, diagonally opposite plots (e.g., 1 and 4) being taken together. Two cemented reservoirs were made, each holding 250 cubic feet, which were filled alternately from the well, the water being baled out of one, while the other was being filled. Each year the treatment given to the plots was reversed, the pair irrigated in furrows one season, being laid out in beds the next. The cropping was arranged on a basis of three crops in two years, a usual rotation on these lands : (1) Ragi (*Eleusine corocana*) from June to September, (2) Sorghum (March to June) and (3) wheat (November to March).

The trials were carried on regularly in these plots until 1916, when they were discontinued, as it was considered that in the conditions described, sufficient data had accumulated. There was still however too much variation to permit of the figures being accepted as they stood, and it was evident that there were other factors influencing the yields obtained. The only factor that could be checked was the natural variation of the plots, and to test this, the plots, since 1915–16, have been cropped uniformly. This standardisation should of course have *preceded* the experiment, but the necessity for taking the probable error into account, was not at the time realized. In any case, this uniform treatment has not produced uniformity in the plots, and in the last crop taken in F. No. 20, the variation between duplicates was as much as 7 per cent.

With this handicap, it is obvious that the figures must be accepted with considerable caution, and the results are accordingly given firstly as obtained, and secondly as affected by a correction figure obtained by averaging all the results obtained from the plots while under uniform treatment, and it is thought that by this means certain lessons of importance can be drawn.

Accordingly, Table I shows the results obtained during the period 1911-12 to 1918-19.

TABLE I.—Plots under uniform treatment.

Year.	Crop.	Plot number.	Yield per acre.		Per cent of average from each pair of plots.	
			Grain.	Straw.	Grain.	Straw.
			Field No. 18.			
			LB.	LB.		
1911-12 ..	Bengal gram (*Cicer arietinum*).	1	352	160	100	73
		4	548	256		
		2	344	308	100	127
		3	560	416		
1914-15 .	Wheat ...	1	692	1,744	107	107
		4	920	1,600		
		2	520	1,296	93	93
		3	880	1,640		
1915-16	Ragi (*Eleusine coro-cana*).	1	2,400	10,768	99·5	92
		4	2,524	13,888		
		2	2,352	12,656	100·5	108
		3	2,604	13,664		
1916-17 ..	Sorghum ...	1	1,808	13,504	95	104·5
		4	2,136	12,064		
		2	1,920	11,312	105	95·5
		3	2,440	12,096		

TABLE I.—Plots under uniform treatment—*cont.*

Year.	Crop.	Plot number.	Yield per acre.		Per cent of average from each pair of plots.	
			Grain.	Straw.	Grain.	Straw.
			Field No. 18—cont.			
			LB.	LB.		
1917-18 ...	Ragi ...	1	2,284	5,880	97·5	105
		4	2,048	6,608		
		2	2,348	5,008	102·5	95
		3	2,198	6,376		
1918-19 ..	Sorghum.	1	1,972	9,582	99	99
		4	2,364	10,608		
		2	2,120	10,016	101	101
		3	2,300	10,544		
			Field No. 20.			
1916-17 ...	Ragi ...	1	2,024	12,768	103·5	101·5
		4	2,148	12,192		
		2	1,980	12,160	96·5	98·5
		3	1,908	12,080		
1917-18 ...	Sorghum.	1	1,396	9,632	103·5	102·5
		4	800	8,304		
		2	1,048	8,544	96·5	97·5
		3	1,000	8,528		

The average percentage of the total crop obtained by each pair of plots respectively is thus:—

TABLE II.

—		Grain.	Straw.
Field No. 18 ..	Plots 1 and 4	99·66	96·75
	Plots 2 and 3	100·33	103·25
Field No. 20 ...	Plots 1 and 4	103·5	102·0
	Plots 2 and 3	96·5	98·0

The variation in F. No. 20 is thus seen to be greater than in F. No. 18, but it must be noted that they are the result of averaging fewer figures. The straw figures are also much less reliable, as in the case of ragi straw, it is almost impossible to carry it in a uniform state of dryness. With these correction figures before us, we may now examine the results obtained from the various crops, and we will first take the ragi crop. Table III gives the yields of four crops in four different seasons, while Table IV gives the amount of irrigation water applied, the number of irrigations, the depth of water applied in each irrigation, and the rainfall during the duration of the crop.

TABLE III.—Ragi (*Eleusine corocana*).

Year.	Treatment.	Yield per acre.		Percentage of average of duplicates to total.				Ridges compared with beds + or —.	
				Under experimental treatment.		Under uniform treatment.			
		Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
Field No. 18.									
		LB.	LB.						
1911-12	Ridge.	1,944	4,400	93·5	94·5	99·7	96·7	- 12·4	- 4·4
		2,424	6,000						
	Bed ...	2,476	5,200	106·5	95·5	100·3	103·3		
		2,492	6,400						
1913-14	Ridge.	1,408	5,328	108·5	108	100·3	103·3	+ 16·4	+ 9·4
		1,556	7,728						
	Bed ...	1,308	4,464	91·5	92	99·7	96·7		
		1,188	6,632						
Field No. 20.									
1910-11	Ridge.	3,064	19,480	104	105	96·5	98	+ 15·0	+ 14·0
		2,884	25,232						
	Bed ...	3,024	17,248	96	95	103·5	102		
		2,484	22,960						
1912-13	Ridge.	3,272	26,704	100·5	104	103·5	102	- 6·0	- 4·0
		3,112	24,336						
	Bed ...	3,232	25,440	99·5	96	96·5	98		
		3,100	21,260						

TABLE IV.

Year.	Treatment.	Irrigation water in inches. Per plot.	Irrigation water in inches. Average.	Number of irrigations.	Depth of water in each irrigation in inches.	Rainfall during crop in inches.
1910–11 ...	Ridge ...	8·32 8·79	8·55	5	1·7	16·85
	Bed ...	9·66 10·39	10·0	5	2·0	
1911–12 ...	Ridge ...	9·16 12·08	10·62	5	2·1	7·40
	Bed ...	12·20 12·56	12·38	5	2·5	
1912–13 ...	Ridge ...	15·3 12·8	14·0	7	2·0	6·50
	Bed ...	16·1 15·1	15·6	7	2·2	
1913–14 .	Ridge ...	13·25 17·24	15·25	5	3·05	7·28
	Bed ...	16·33 17·21	16·77	5	3·4	

NOTE.—About six inches of rain which fell just before harvest in 1910–11 was not useful to the crop.

The figures show that on the corrected basis, the ridge system has on two occasions given a better crop than the bed system, and on two occasions the crop has been inferior. In every case there has been a distinct saving of water.

Ragi is a transplanted crop: it is grown in a seed-bed and the seedlings are lifted and planted out when a few weeks old in the field. There is no difficulty in planting them along the sides of the ridges, but it was found that on the whole, fewer seedlings were planted per unit of area, than when planting was done in beds, and this cause of variation had to be watched: in one case the ridged area was only getting 150,000 seedlings to the acre, while the beds were being planted at the rate of 185,000. This difference may not produce much effect, but it should be remembered, in case the plants are not able to grow sufficiently to supply the deficiency.

In one case of failure of the ridge system, that in 1911–12, an outside varient was admittedly introduced, in the much poorer stand of green manure, which was ploughed in for this crop. With these reservations, the figures may be accepted as being fairly reliable. In the year of heavy rainfall, 'ridges' showed up best, and this probably gives the clue to much that is perplexing in this question. It is not possible to give such heavy irrigations in furrows as in beds, though with skilful irrigators, it is probably possible to give sufficient. No standard was laid down in these plots, and the distribution of water was left to the irrigator, who being unused to ridges, did not apply as heavy a watering as could have been done had greater skill been available. Ragi is grown here in the monsoon, and the amount of added water is relatively small,—in one year less than 10 inches,—and that was the year in which the ridges did very well. They did well also in 1913–14, when the amount of water applied in each irrigation was heavy. It seems clear that the adoption of this system for ragi offers chances of success, provided the season is not too dry, and granted ordinary skill in applying the water. The saving of water is undoubted, and has amounted to about 1·5 inches, or about one-eighth of the total used.

In the case of the next crop, *Sorghum*, the conditions are very different. The crop is not transplanted, and as it is not sown with natural rainfall, irrigation is necessary to start germination. The customary method of doing this is to broadcast the seed ; cover it lightly with a wooden plough, lightly scrape the surface soil by *mamuti* (mattock) to form the ridges which bound the beds, and then let in the water, flooding each bed in turn. This proves in the hands of the local operators successful, and a full stand is usually obtained. If furrow irrigation is to be adopted, the matter is not so simple, and we have tried various ways. The field was flooded by roughly dividing it into checks, and then when sufficiently dry, ploughed; the seed was then drilled in lines in the moist soil and left to grow until old enough to stand ridging. Another method was to ridge the land up, and sow the seed either on the top or on the sides of the ridges, but this never resulted in a full plant. In fact, none of the methods proved satisfactory, and in most cases resource was had to transplanting to fill up the gaps. This again implied more water, as an extra flooding had to be given to keep these going. The transplanted seedlings, moreover, never grew so well as those sown. The tables below show the results obtained, which are all in favour of the flooding method. The saving of water, due to the extra watering, has been negligible and the yield of grain has been decidedly, and that of straw seriously, below the yields obtained from the crop in the beds. As showing the seasonal variation which may occur, it is interesting to note that in 1911-12, the rainfall was so ample and well distributed, that practically no irrigation was given at all, and no comparative results were obtained.

TABLE V.—Sorghum.

Year.	Treatment.	Yield per acre in lb. Grain.	Yield per acre in lb. Straw.	Percentage of average of duplicates to total. Under experimental treatment. Grain.	Under experimental treatment. Straw.	Under uniform treatment. Grain.	Under uniform treatment. Straw.	Ridges compared with beds + or –. Grain.	Ridges compared with beds + or –. Straw.
				Field No. 18.					
1912–13	Ridge.	2,404	7,120	98·5	96·2	100·3	103·2	— 3·6	— 14·0
		2,632	7,056						
	Bed ...	2,552	7,408	101·5	103·7	99·7	96·7		
		2,648	7,856						
1914–15	Ridge.	2,336	4,368	100·0	85·0	99·7	96·75	+ 0·6	— 23·5
		1,872	4,304						
	Bed ...	2,016	5,184	100·0	115·0	100·3	103·25		
		2,180	6,592						
				Field No. 20.					
1913–14	Ridge.	2,744	6,144	94·0	92·5	96·5	98·0	— 5·0	— 11·0
		2,600	5,824						
	Bed ...	3,216	7,280	106·0	107·5	103·5	102·0		
		2,880	6,544						
1915-16	Ridge.	2,068	7,760	97·0	100·0	103·5	102·0	— 13·0	— 24·0
		1,756	7,904						
	Bed ...	2,132	9,056	103·0	110·0	96·5	98·0		
		1,932	9,952						

TABLE VI.

Year.	Treatment.	Irrigation water in inches. Per plot.	Irrigation water in inches. Average.	Number of irrigations.	Depth of water in each irrigation. Plot.	Depth of water in each irrigation. Average.	Rainfall during crop in inches.
1912–13 ..	Ridge ...	10·7	10·2	5	2·1	2·25	4·90
		9·8		4	2·4		
	Bed ...	11·8	10·5	5	2·4	2·35	
		9·3		4	2·3		
1913–14 ...	Ridge ...	15·4	14·65	7	2·2	2·1	2·13
		13·9		7	2·0		
	Bed ...	14·0	14·1	6	2·3	2·35	
		14·2		6	2·4		

Year.	Treatment.	Irrigation water in inches.		Number of irrigations.	Depth of water in each irrigation.		Rainfall during crop in inches.
		Per plot.	Average.		Plot.	Average.	
1914-15 ...	Ridge ..	20·34 20·90	20·6	6 6	3·4 3·5	3·45	2·35
	Bed ...	19·1 21·3	20·2	5 5	3·8 4·3	4·05	
1915-16	Ridge ..	12·92 13·19	13·0	5 6	2·6 2·2	2·4	6·75
	Bed ...	13·09 15·90	14·5	5 6	2·6 2·7	2·65	

The third crop tested was wheat. As this crop carries on well into the hot dry weather of February and March, it requires generally more water, especially in its later stages, than the others, and as we have suggested above, it is where such intense irrigation is needed, that 'ridges' are likely to fail. The results obtained (see Tables VII and VIII) bear this out.

TABLE VII.—Wheat.

Year.	Treatment.	Yield per acre in pounds.		Percentage of average of duplicates to total. Under experimental treatment.		Under uniform treatment.		Ridges compared with beds + or −.	
		Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
				Field No. 20.					
1911-12 ...	Ridge.	1,236 1,692	2,000 2,384	98·0	108·5	96·5	98·0	+ 3·0	+ 21·0
	Bed ...	1,680 1,376	2,192 1,504	102·0	91·5	103·5	102·0		
				Field No. 18.					
1912-13 ...	Ridge.*	1,358	...†	86·5	...	99·7	...	−26·4	...
	Bed ...	1,696 1,852	... ...	113·5	...	100·3	...		

* The yield of duplicate plots were accidentally mixed up before weighing.
† No weighments were taken for straw.

TABLE VIII.

Year.	Treatment.	Irrigation water in inches. Per plot.	Irrigation water in inches. Average.	Number of irrigations.	Depth of water in each irrigation. Plot.	Depth of water in each irrigation. Average	Rainfall during crop in inches.
1911–12 ...	Ridge.	14·97 14·96	14·96	5 5	3·0 3·0	3·0	4·80
	Bed ...	17·43 16·53	16·98	5 5	3·5 3·3	3·4	
1912–13 ...	Ridge.	14·14 13·72	13·93	7 7	2·0 2·0	2·0	12·50 between 1st and 2nd irrigation.
	Bed ...	17·66 18·51	18·08	7 7	2·5 2·6	2·55	

The saving of water is more marked than in the other crops considered, evidently because of the greater advantage conferred by the furrows in the drying weather of February, but the inadequacy of the water given is no doubt the cause of the failure of the 'ridges' plots.

As a general conclusion, we may say that distinct benefits can be conferred by the adoption of the furrow system of irrigation, but only under certain conditions, namely, that the application is made carefully and that economy in watering is not overdone. It is an excellent illustration of the impossibility of importing ready-made maxims from other countries, because, were we to depend on American or European experience, we should not question the benefits of this method of irrigation. We are dealing here with conditions of greater heat and greater evaporation, and consequently larger applications of water are necessary, and it is this that militates against the success of the furrow.

The land has to be levelled carefully and the actual application of water along the furrow is not only a novelty, but actually requires more care and skill than the operator is likely,—even under supervision,—to possess. Hence it is where the applications need only to be light, that this system has proved successful. Where heavy watering is needed, the system breaks down, because the quantity of water needed can only be given by numerous small waterings, with their consequent waste of labour and loss by evaporation.

SUMMARY.

1. A given quantity of water, provided it is not excessive, can be applied to a crop more economically by running it along furrows than by flooding beds or checks with it.

2. The actual quantity of water that can be applied at a single irrigation is less in the furrow system, than in the check system.

3. Thus, if a crop requires a heavy irrigation it is better to flood, because the smaller quantity of water applied at each furrow irrigation, will have to be made up by extra waterings, and these are most uneconomical.

4. The practical application of these results at Coimbatore, is that for ragi grown in the monsoon, the system can be recommended, but for wheat which needs heavier watering, it cannot.

5. The practical difficulty of obtaining a full plant with a crop which requires sprout irrigation, has prevented its being a success with *Sorghum*.

DUTY OF WATER WHEN IRRIGATING BY PUMPING.

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Next to the Divi Pumping scheme which is for irrigating about 50,000 acres, the biggest pumping installation in the Presidency is that which was erected by the Pumping and Boring Department on the right bank of the Main canal, Kistna Western Division, for the Atmakur Lift Irrigation Company. The plant was originally designed to irrigate 500 acres of paddy cultivation, the water being obtained from the main canal, and it consists of two oil engines, each of 12 B.H.P., each driving a 10-inch centrifugal pump and each capable of delivering 2,000 gallons of water per minute (or 19,200 cubic feet per hour). During 1909 and 1910 407 and 430 acres respectively were irrigated. In 1911 a 28 B.H.P. oil engine and 14-inch centrifugal pump capable of delivering 3,920 gallons per minute (or 37,632 cubic feet per hour) were added. In 1912 an area of 750 acres was irrigated and during 1917 the cultivation was increased to 830 acres.

The paddy raised is a six-month-variety crop common in the Guntūr district.

The soil is mostly black alluvial excepting about 200 acres which is slightly sandy. Generally speaking the soil is representative of the best soil under the Kistna Delta.

The following figures extracted from the records of the installation are of interest.

Table A gives the number of hours a 10-inch pump worked for each of the six months during the cultivation seasons of 1909, 1910, 1912 and 1917.

It must be remembered that during 1909 and 1910 only the two 10-inch pumps were in existence and during 1912 and 1917 there was a 14-inch pump in addition to the 10-inch pumps. The number of hours of pumping is calculated in the following manner. If one 10-inch pump worked 110 hours in a month and the other 10-inch pump for 130 hours in the same month the total number is shown as 110 + 130 = 240 hours for the month. The delivery of the 14-inch pump being 3,920 gallons per minute or very nearly double that of the 10-inch pump (2,000 gallons) one hour's pumping with the 14-inch pump is taken as two hours pumping with 10-inch pump, so that if the 14-inch pump worked 250 hours in a month while the 10-inch pumps worked 180 hours each, the total hours of pumping for the month is taken as 250 × 2 + 180 + 180 = or 860 10-inch pumping hours.

TABLE A.

Year.	Duration of the season.	Number of days.	Number of 10-inch pump hours.							Total number of 10-inch pump hours.
			June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	
1909	21 June to 15 Dec.	178	110	246	498	613	1,072	1,084	595	4,218
1910	21 June to 16 Dec.	179	...	160	684	144	18	472	270	1,748
1912	21 June to 15 Dec.	178	93	428	431	665	1,556	1,290	478	4,941
1917	16 June to 10 Dec.	178	...	1,271	428	90	1,080	660	201	3,730

Table B gives the quantity of water supplied to each acre in inches depth during each month. The figures in this table are worked thus :—

In July 1909 the water pumped was equivalent to the discharge of a 10-inch pump for 246 hours which is 246×19,200 cubic feet. During the year 407 acres were irrigated so that the depth of water pumped over one acre is :

$$\frac{246 \times 19{,}200 \times 12 \text{ inches}}{407 \times 4{,}840 \text{ sq. yds.} \times 9 \text{ sq. feet.}} \text{ or } 3{\cdot}20 \text{ inches.}$$

Similarly taking the month of July of the year 1917 when 830 acres were irrigated the depth of water supplied to each acre was :

$$\frac{1{,}271 \times 19{,}200 \times 12}{830 \times 4{,}840 \times 9} \text{ or } 8{\cdot}10 \text{ inches.}$$

TABLE B.—*Depth in inches for water pumped per acre.*

Year.	Acres irrigated.	Equivalent inches depth.							Total.
		June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	
1909 ...	407	1·43	3·20	6·47	7·97	13·94	14·09	7·73	54·83
1910 ...	430	...	1·97	8·41	1·77	0·22	5·82	3·32	21·51
1912 ...	750	0·66	3·02	3·04	4·69	10·97	8·99	3·27	34·74
1917 ...	830	8·10	8·10	2·73	0·57	6·88	4·20	1·28	23·76

Table C gives the rainfall in inches at Mangalagiri, a station 2½ miles from the land irrigated, as recorded in the *Fort St. George Gazette*. The figures in the table represent the rainfall, during the cultivation period which is given in table A, columns 2 and 3. For example the figure 6·21 for June 1917 represents the rainfall between 16th and 30th of June and does not include the rainfall previous to the 16th.

TABLE C.—*Rainfall in inches at Mangalagiri.*

Year.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total.
1909 ...	5·11	7·96	7·64	3·57	1·48	...	...	25·76
1910 ...	6·55	7·29	4·82	11·13	11·61	3·31	...	44·71
1912 ...	4·69	11·59	7·71	4·70	1·41	2·30	...	32·40
1917 ...	6·21	3·70	8·24	9·49	3·40	11·56	...	42·60

Table D gives the total water in inches-depth per acre due to pumping and rainfall (combined). This is obtained by adding together the figures given in Tables B and C.

TABLE D.—*Total depth in inches per acre due to pumping and rainfall.*

Year.	June	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total.
1909 ...	6·54	11·16	14·11	11·54	15·42	14·09	7·73	80·59
1910 ...	6·55	9·26	13·23	12·90	11·83	9·13	3·32	66·22
1912 ...	5·35	14·61	10·75	9·39	12·38	11·29	3·37	67·14
1917 ...	6·21	11·80	10·97	10·06	10·28	15·76	1·28	66·36

There are four reasons to explain the very high figure of 80·59 inches for the year 1909—

(1) It was the first year of cultivation. The lands were dry lands from time immemorial. Consequently excessive quantity of water was required during the first year of their conversion into wet lands.

(2) The ryots were not as experienced in the proper distribution of water as they later on became.

(3) The channels being new, water was wasted due to the frequent bursting of the bunds.

(4) About 200 acres out of 407 were sandy and slightly saline and large quantities of water were required for their reclamation.

In the year 1910 the figures obtained were better, because the channels were properly aligned and distribution sluices constructed and a definite programme of turns for watering the several plots of land was arranged for the ryots so that each ryot received his proper share of water at regular intervals. The channel is divided into 10 reaches each commanding a block of 100 acres. If the pumps work 10 hours a day, each block is supplied with 2 inches of water, and in nine days the whole area is irrigated. In times of drought the pumps are worked for a larger number of hours and then each acre can be irrigated with 2 inches depth once in five days.

A comparison of tables A and C shows how the hours of pumping varied with a rainfall—the more rain the less pumping required and vice versa.

Table E gives the duty of water during the respective years. Column 6 represents the duty of water under pumps and column 7 the duty of water by gravity flow from the main canal for the lands on the left bank of the Main canal just opposite the pumping installation. The latter figures are given by the Public Works Department. The duty is worked as follows:—Take the year 1909. Referring to table A, the last column shows that 4,218 hours (10 inches-pump-unit) pumping was done. The discharge of a 10-inch pump is 19,200 cubic feet per hour and the total quantity of water pumped during the year was 4,218 hours × 19,200 cubic feet. Table A, column 4, shows the duration of the season to have been 178 days so that the total quantity of 4,218 × 19,200 is equivalent to the quantity which would have been supplied with a constant uniform supply during the 178 days of 4,218 × 19,200 ÷ 178 × 24 × 60 × 60 seconds or 5·264 cubic feet per second. The land irrigated during the year 1909 as shown in table B was 407 acres. Hence 1 cusec irrigated 407/5·264 or 77·3 acres. This figure 77·3 acres is called the duty of water per cusec.

TABLE E.

Year.	Area in acres.	Duration of season.	Total No. of 10″ pump hours.	Equivalent cusecs during the season.	Duty of water per cusec in acres by pumping.	Corresponding duty under P.W.D. Main canal.
1909 ...	407	178	4,218	5·264	77·3	95
1910 ...	430	179	1,748	2·17	198·1	165
1912 ...	750	178	4,941	6·168	121·5	120
1917 ...	830	178	3,730	4·462	186·0	175

From the above table it will be seen that, excepting during 1909 (for reasons explained under Table D), the duty of water by pumping has been better than that by gravitation (P.W.D.).

As a matter of fact, in 1911, the Public Works Department sanctioned the increase in the ayacut from 500 acres to 1,000 acres after satisfying themselves that the duty during 1910 by pumping was better than that by irrigation by gravity.

Inference from Tables C and D.

Leaving the year 1909 out of consideration for the reasons given under Table D, it will be seen from the last columns of the Tables B, C and D that the deficit in rainfall had to be made up by pumping, e.g., in the year 1912. Taking the average for the years 1910, 1912 and 1917 the total quantity (pumping and rainfall) of water in inches supplied for paddy was as follows:—

—	Half of June.	July.	Aug.	Sep.	Oct.	Nov.	Half of Dec.	Total.
	6·04	11·89	11·65	10·78	11·50	12·06	2·66	66·58
				or in round figures.				
	6·00	12·00	11·75	10·75	11·50	12·00	2·50	66·50

From this it would appear that the total quantity of water required for the six-month paddy crop is about 60·9 or nearly 61 inches for reasons explained in remark (*a*) under Table F, that is, a little over one-third of an inch of water per day on the average including rainfall and any deficit in rainfall has to be made up by pumping. This one third of an inch per day represents only the average demand.

The maximum and minimum demands during different stages of cultivation are altogether different as shown hereafter.

The total duration of paddy cultivation may be divided into three definite periods:

(1) First period for raising of seedlings.

(2) Second period for the transplantation.

(3) Third period for the maturing of the crop.

Detailed figures giving the actual quantity supplied during the different periods are available for the year 1917 of the working of the Atmakur installation when 830 acres were cultivated.

TABLE F.

Duration.	No. of days.	No. of rainy days.	Quantity of water pumped in inches per acre during the period.	Rainfall in inches during the period.	Total quantity in inches per acre.	Inches per day including rainfall during the period.
First period, 16th June to 4th July.	19	10	Nil	6·61	6·61	·3489(*a*) (·0232)
Second period, 5th July to 11th Aug.	38 (*b*)	11	10·83	6·40	17·23 (*c*)	·4534
Third period, 12th Aug. to 10th Dec.	121	32	12·93	29·59	42·52	·3515
Total ...	178	53	23·76	42·60	66·36	·3728
		Average depth per day for the season				·33815(*a*)

Remarks.—(*a*) This figure appears high, but considering the area of seedlings is about 1/15th the total area cultivated, the ·3489 inch of water required for the actual seedling area is equivalent to only ·3489/15 or ·0232 inch over the whole cultivated area.

(*b*) The period of transplantation extends over four to five weeks according to the facilities for obtaining labour, etc., but 38 days for 830 acres is a fair figure.

(*c*) 17·23 inches of water is required for transplantation. This agrees with the foot-note on page 31 (Vol. IV, Bulletin 71), in Mr. R. C. Wood's "Irrigation" which runs thus :—

"For the period of four weeks during which transplantation was in progress 16 to 18 inches of water, including rain, was found sufficient for transplanting and for maintaining the crop as soon as transplanted." (This is quoted from the Public Works Circular Memorandum No. 946-E, dated 22nd June 1915, and the Public Works Department fix the maximum area under any canal on this basis.

'The duty of water' during the transplantation season is always very low compared with the 'duty of water' during the whole season. 'Duty' of water by pumping for the different periods in the year 1917 works out as follows:—

	ACS.
Duty of water during transplantation period ...	83·6
Duty of water during maturing period ...	222·5
Duty of water from the commencement of transplantation to the end of maturing period.	159·2
Duty of water from the raising of seedlings to the end of maturing period	178·2

It may be of interest to find out the Maximum Area that can be irrigated by an installation pumping 8,000 gallons per minute.

It has already been shown that about 18 inches of water per acre is required for the transplantation period; if the monsoon fails completely during the period, the whole 18 inches of water per acre has to be supplied by the installation to carry on the transplantation operations. This quantity has to be supplied within a limited period of 38 days. But the experience at Atmakur installation during the last ten years shows that every year the bunds of the channels breach occasionally and it was found impossible to pump for three days during this period (on the average). Again at the commencement of the season it was found undesirable to work all the three pumps simultaneously for the first two or three days, as the channel-bunds are generally full of sun-cracks due to the previous hot weather and also they are damaged by cattle, and to allow time for the channels and bunds to settle properly only one pump is worked on the first day, two pumps on the second day, and all the three put on from the third day. This is equivalent to a loss of one day. Thus a loss of altogether four days has to be counted upon and the total quantity of 18 inches per acre has to be pumped in 38 minus 4 or 34 days. It is not possible to work for more than 20 hours a day, especially with oil engines working on liquid fuel, as the vapouriser gets blocked with carbon deposit and a fresh vapouriser has to be fitted on.

Hence the total quantity that can be pumped during 34 days is 34 × 20 × 60 × 8,000 gallons or

52,224,000 cubic feet. A supply of 18 inches depth of water per acre is equivalent to 4,840 × 9 × 3/2 cubic feet or 65,340 cubic feet and the total quantity pumped in 34 days will irrigate 800 acres nearly. This is the maximum area that the installation can command in a year when the rains absolutely fail during the transplantation period. In a year when there is 18 inches rainfall at the commencement of transplantation period, an unlimited area can be transplanted without any pumping at all. But should the rains fail during the maturing period, the necessary quantity during that period has to be supplied by the pump. It has been shown that each acre requires a total of ·3515 inch per day during the maturing period and this quantity is equivalent to 4,840 × 9 × ·3515/12 cubic feet or 1,276 cubic feet per acre per day. During a day, the pumps can supply 20 × 60 × 8,000 × 4/25 cubic feet or 1,536,000 cubic feet of water or supply roughly 1,536,000/1,276 = 1,200 acres with the quantity necessary during the maturing period. Thus the limit of the irrigating capacity of an installation discharging 8,000 gallons per minute is from 800 to 1,200 acres according to the rainfall.

This limit of 800 to 1,200 acres applies to lands round the Atmakur installation, which represent some of the best soils in the Presidency. It will be noted that in the above calculations no allowance is made for any accidents to the engines or pumps which might necessitate stoppage of pumping to effect repairs. It is safe to take 800 acres as the area (the average for the Presidency) that can be cultivated by a pump supplying 8,000 gallons per minute.

Roughly speaking, the number of acres that can be cultivated by a pump is equivalent to its discharge in gallons per minute divided by 10. This rule might safely be applied to all pumps whose discharge is above 4,000 gallons per minute, but for smaller pumps delivering a lesser quantity per minute the actual area that can be cultivated is much less owing to the heavy loss due to percolation and seepage in distributing channels. This aspect is discussed below.

Loss of water due to percolation in water courses.—Colonel Clibbern in his paper relating to construction of wells for irrigation in North-West Provinces, page 15, paragraphs 98 and 100 says :

"A matter intimately connected with the construction of wells is the loss due to percolation from water courses. The mean loss is about two cubic feet per foot run during a day of nine hours. The loss of area varies from 30 to 50 per cent per well for a water course of 500 feet long. Experiments made on the Anupshar Branches, Ganges Canal, shows, out of a total supply of one cubic foot per second, a loss of 0·5 cubic foot per second in a distance of 1·5 miles, equivalent to 2 cubic feet per foot run in nine hours."

This point has been well brought out in Mr. Wood's "Irrigation", pages 27 and 28. The effect of this heavy loss due to percolation in water courses must be carefully considered in determining the maximum area which can be irrigated by a pump.

Table G gives the maximum area irrigable with different sizes of pumps making allowances for the percolation mentioned above.

TABLE G.

Size of the pump. (1)	Discharge per minute, in gallons. (2)	Commandable area per acre. (3)	Approximate length of watercourses for the area. (4)	Total quantity discharged in cubic feet in a day of 20 hours. (5)	Loss due to percolation at 2 cubic feet per foot run of watercourse for every 9 hours. (6)	Nett quantity received in fields in twenty hours. (7)	Percentage of loss due to percolation according to column 6. (8)	Approximate maximum commendable area. (9)	Maximum area as cultivated. (10)	Percentage of loss of area as cultivated. (11)
14″ 10″	...	...	...	...	...	...	...	...	...	...
10″	8,000	800	13,200	1,536,000	58,666	1,477,334	3·2	800	850	...
12″	2,800	280	604	537,600	26,888	508,712	5	275	300	...
10″	2,000	200	5,400	384,000	24,000	360,000	6·25	195	200	...
8″	1,280	128	4,025	245,760	17,888	227,872	7·3	122	115	10
6″	720	72	2,925	138,240	13,000	125,240	9·3	68	60	16·66
5″	500	50	2,250	96,000	10,000	86,000	10·5	46	40	20
4″	320	32	1,725	61,440	7,666	53,774	12·5	30	24	25
3″	180	18	1,300	34,560	5,777	28,783	16·5	15	12	33·33
2½″	120	12	1,150	22,040	5,111	16,929	23	9	7½	35½
2	80	8	864	15,360	3,840	12,138	25	6	5	37½
1½″	40	4	450	7,680	2,000	5,680	26	3	2½	37½

Columns (1) and (2) give the size of the pump and their discharge in gallons per minute (G.P.M.) respectively.

Column (3) the area which can be irrigated as per formula 1/10 × No. of G.P.M.

Column (4) gives the minimum length of water course in feet that the area requires for irrigating under the best conditions, i.e., if the field is a square and the pump situated in the centre of it. Under any other conditions the length of water courses will be increased which may amount in some cases to double the length given in the table.

Column (5) gives the quantity discharged by the pump in cubic feet in 20 hours, which is the maximum time a pump can be worked in a day of 24 hours.

Column (6) gives the loss due to percolation in 20 hours in the lengths of the water courses shown in column (5), at 2 cubic feet per foot run for every 9 hours.

Column (7) is the nett available quantity of water per day for actual irrigation.

Column (9).—It has been shown already that a supply of 1,536,000 cubic feet of water for 20 hours at the pump is irrigating about 800 acres ; and this quantity allowing for the loss due to percolation is equivalent to a nett 1,477,337 cubic feet for a day of 20 hours. Eight hundred acres are being irrigated with this quantity. The figures in this column for other sizes of pumps are calculated in the same proportion for the nett available quantity in column (7).

Column (10) gives the maximum area that is now cultivated with the different sizes of pumps in this Presidency. It will be seen that for pumps of ten inches and above, the area actually being cultivated is slightly greater than shown in column (9), while for smaller pumps the area is less. This is evidently due to the fact that with the smaller supplies the rate at which the water flows over the field is slow, thus allowing a large quantity to soak into the soil, while with the larger quantities the water flows quickly over the fields and there is no loss due to percolation in the fields. Other reasons which contribute to the area being less are (1) the porosity of the soil, (2) the pumps not being worked for 20 hours, and (3) the water courses being much longer than shown in column 4. The figures in column (10) may be taken as the maximum area for the respective pumps for all practical purposes, as some or all the causes enumerated above will exist for all agriculturists, and, the question of economics of irrigation by pumping will have to be based on this figure. In 70 to 80 per cent of the existing installations the actual area irrigated is much less than that shown in column (10), but this is mainly due to the negligence of the ryot.

NOTE ON THE FERMENTATION OF GREEN MANURE.

BY ROLAND V. NORRIS, D.SC., F.I.C.,

Government Agricultural Chemist, Coimbatore.

While the changes involved in the rotting of farmyard manure have received the attention of a large number of workers and are beginning to be understood in some detail, the fermentation of green manure has been comparatively little studied. This is perhaps only natural as in the case of farmyard manure, owing to the necessity for storage, the fermentation changes resulting have always been prominently brought to notice and the obvious necessity of attempting to control the process in order to prevent loss of valuable manurial ingredients has led to numerous investigations. In the case of green manures, however, there has been no necessity for storage and the changes taking place after the addition of the manure to the land being therefore far less obvious, have attracted much less attention.

In view of the widespread use of green manure it seems highly desirable that the changes taking place after its application to the soil should be thoroughly studied, for these changes, in addition to providing direct plant food, have a considerable influence on the mineral constituents of the soil and little is as yet known as to the nature and extent of this influence or as to how far it is capable of control. Investigations of the kind indicated are particularly necessary in the case of wet land cultivation, since the work of Harrison and Subrahmanya has shown that under such conditions a very large proportion of the nitrogen added in the green manure is liberated in the free state, i.e., in a form useless to the crop, and that the chief value of the manure must be attributed to its indirect action which leads to the thorough æration of the roots. The question then arises, can we improvise any methods which will obviate this waste of nitrogen? Under the usual method employed of puddling in the fresh green manure it seems doubtful whether much can be done in this direction as the process is obviously almost impossible to control. In 1916 however Hutchinson suggested an alternative method of dealing with green manure, his proposal being to collect the manure in pits, allow this to rot and apply the fermented manure to the land. The objection that has been raised to this method is an economic one, viz., the cost of labour. Experience on the Central Farm, Coimbatore, however, would appear to indicate that this objection is not a serious one and is more than compensated for by the advantages gained. We must consider what these advantages are likely to be. The most obvious one is that the fermentation involved is capable of a large measure of control. We can, for instance, vary the degree of æration, we can vary the amount of moisture and by the addition or not of substances such as lime and other salts we can modify the nature of the fermentation to a very considerable extent. A second advantage moreover is that the manure is brought into a much more readily available form and the immediate return should therefore be greater.

Dealing with the first point, the prospects of successful control, little has so far been done to see how far this will lead. Hutchinson in his experiments tried anærobic and ærobic fermentation. The resulting manures were tested with tobacco the best results being obtained with that prepared ærobically. We are here dealing with a dry crop however and the advantage of the ærobic method was doubtless due to the production of nitrates which did not obtain when anærobic conditions prevailed. In the case of paddy, however, we do not want production of nitrates as these will eventually either be washed out of the soil or lead to loss of nitrogen by denitrification. Hence in the case of green manure intended for paddy cultivation the anærobic method is likely to lead to better results. Little work has however yet been done in the way of examining the various products of this fermentation from a quantitative point of view or studying the change in these produced by alterations in the conditions. In particular no figures are yet available to show what loss of manurial ingredients takes place under such treatment. We can, however, derive a certain amount of information by considering some of the changes taking place in the fermentation of farmyard manure which is probably closely related. The most recent study of this question is that made by Russell and Richards (Journal of Agricultural Science, 1917, Vol. 8, page 494), their chief object being to find out the conditions leading to the least loss of nitrogen and the reason why this loss occurred. Without going into details it is sufficient to state these authors found that when the conditions were either completely anærobic or completely ærobic the loss of nitrogen was reduced to a minimum although the form in which the nitrogen was present, e.g., NH_3, amides, etc., varied greatly in the two cases. On the other hand when the conditions were intermediate, i.e., partially anærobic and partly ærobic as will obtain in loosely made heaps or in heaps which are remade, then large losses of nitrogen occur. They were also able to show that the loss of nitrogen is not, as frequently stated, chiefly due to volatilization of ammonia, the greatest loss being caused by the evolution of gaseous nitrogen. They were further of opinion that this evolution of nitrogen was not a simple case of denitrification but due to the decomposition under ærobic conditions of unstable nitrogenous compounds produced during anærobic fermentation and *vice versâ*. Now this latter observation is of considerable interest when paddy conditions are under consideration for it has yet to be shown how the gaseous nitrogen of paddy fields is produced. Under the conditions of cultivation it is extremely unlikely that any production of nitrate can take place even in the surface film and hence the process cannot be a simple case of denitrification.

Russell and Richards as a result of their investigation recommend that farmyard manure should be stored under conditions as completely anærobic as possible and at a temperature of about 26° C. The particular advantage of this temperature is not definitely stated but doubtless this favours some particular group of organisms and so determines the type of fermentation. We may reasonably expect then that in fermenting green manure we shall probably suffer least loss of manurial ingredient under something like the same conditions. These conditions are advantageous for another reason in that they are precisely those which favour the maximum degree of ammonification which is the stage of decomposition we most require. The course of the fermentation can be modified in other ways. Potter and Snyder (Journal of Agricultural Research, 1917, Vol. X, page 677) have shown that by the addition of lime the fermentation of green manure in the soil as measured by the evolution of CO_2 is considerably accelerated. This result is probably largely due to the neutralisation of acids produced during the fermentation which would otherwise have an inhibiting effect on the bacteria responsible. Preliminary experiments made in this laboratory however indicate that this is not the only result, the type of fermentation in presence of lime leading to changes of a putrefactive nature, i.e., production of amines, etc. The experiments, however, confirm Potter and Snyder's results that the decomposition is more rapid and complete in the presence of lime. The production of amines again can be prevented according to Hutchinson without inhibition of ammonification by the addition in small quantities of certain salts such as $CuSO_4$ and KCN.

One other aspect of the case remains to be considered. There is abundant evidence that the products of fermentation of organic matter such as green manure have a powerful solvent action on insoluble mineral fertilisers such as rock phosphate, etc., and render these more or less available.

The best method of applying this property would appear to lie in the addition of the mineral fertiliser, e.g., flour phosphate, etc., to the fermenting green manure before application to the land. Under the conditions indicated—anærobic decomposition in presence of plenty of moisture—the fermentation is of a very energetic nature and the products being naturally much more concentrated than is possible where the green manure has been puddled in the ordinary way, the maximum solvent power would be produced. The phosphate would moreover assist the fermentation by preventing undue accumulation of acid. The net result should therefore be the production of a highly decomposed manure containing a considerable amount of soluble phosphate and with a large proportion of its nitrogen in the most suitable form. The problem, however, is not so straightforward as would at first sight appear. A considerable number of experiments on this subject have already been made on the laboratory scale by Rao Sahib Ramaswami Sivan and the results have been of a somewhat unexpected nature. The change in the availability was in nearly every case confined to the first seven days of the experiment, little advantage resulting, as a rule, from longer periods of composting while in some cases the amount of soluble phosphate actually diminished when the experiment was prolonged. It is possible that the conditions under which the above experiments were carried out did not lead to the most energetic type of fermentation. But there would appear to be other factors concerned which must form the subject of further investigation. One important consideration remains.

The work of Harrison and Subrahmanya indicates that one of the chief functions of green manure as at present applied in paddy cultivation is its indirect action in leading to thorough æration of the roots. This action is derived from the fermentation of the carbohydrates present in the manure leading to products which, under the influence of the surface film, result ultimately in the liberation of oxygen. In any preliminary fermentation a good deal of the carbohydrate matter will be destroyed and it will be a matter for experiment to determine whether the anticipated saving in nitrogen compensates for this loss. The conditions to aim at in the preliminary fermentation would appear to be stimulation of the nitrogenous decomposition and restriction of the carbohydrate fermentation. Whether such a combination be possible remains to be seen but this would undoubtedly lead to the best results so far as paddy requirements are concerned.

The above notes indicate that there are many possibilities of improvement on the present system. It is, however, useless to enlarge on these at this stage, much experimental work being required to see how far these possibilities are capable of realization. It is not necessary, however, that field trials should be delayed pending the completion of laboratory experiments. On the contrary, comparative experiments using plots treated in the ordinary way and plots in which the green manure added has undergone a preliminary fermentation under various conditions, should yield results of a highly interesting and instructive nature.

ECONOMICS OF THE GHI TRADE.

By D. ANANDA RAO, B.SC.,
Assistant Principal, Agricultural College.

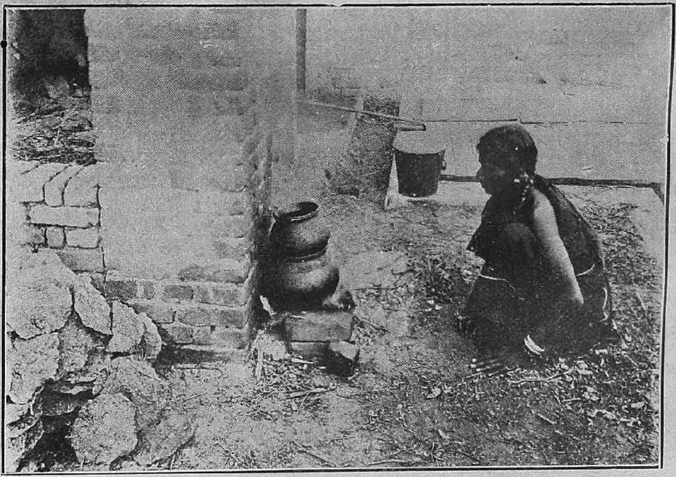
Although the manufacture of butter as such plays no important part in Indian households, except occasionally as a medicine, it is, however, in a clarified form invaluable. It then goes by the name of the 'ghi' of commerce,—a commodity which forms a portion of the food of the people of the country. It goes without saying that if dairy products are adulterated, ghi is no exception to the rule. It is especially so because of the difficulty of the consumer to detect the adulterant. An experiment was initiated to investigate the details of ghi manufacture with a purpose to note if the present method of manufacture of pure ghi is on an economic basis or not.

PART I.

Milk, naturally, is the basis of ghi manufacture, and upon the quality of it, depends the success or failure of ghi trade. Butter is but an intermediate product in the process. The different processes are herein briefly recorded. Milk, preferably buffalos', is boiled on an open fire, the chief fuel used being dry cow-dung cakes. These are preferred in virtue of their slow burning quality—a quality essential in milk boiling. A mud pot is the common utensil used for such a purpose, which is covered with another mud pot when milk is boiled (Plate II). During boiling, the smoke freely permeates through the milk, which gives the milk and curd the characteristic smell with which all are familiar. The milk is then allowed to cool for a while after it is first brought to the boil, when a small quantity of the previous day's curd is added to sour it. It is then laid aside till next morning. There are two methods common around Coimbatore in the disposal of the curd so obtained; either the whole curd is churned or only the top portion is skimmed and churned. In both cases the Indian beater churn is the instrument employed (Plate III). The method of skimming with the hand is shown in Plate IV. The skimmed curd naturally retains a large portion of cream. Where the latter practice is adopted, the rest of the curd is sold as such, being previously broken up into large pieces, and mixed with a judicious amount of buttermilk * obtained from churning the skimmed curd. Where the whole curd is churned, the by-product is the buttermilk which ultimately contains equal quantities of water added at different periods of the operation. In whichever way the butter is made, hands are freely used in the operation (Plate V). When butter has formed, it is removed with the hands into another vessel, and by further agitation of the vessel, some more of the butter is squeezed out. The beater churn is then carefully scraped with the fingers to remove the last traces of butter adhering to it. When butter undergoes such a treatment at the hands of the curd woman, the shades of colour that it takes are easier imagined than described ! When all the butter is removed it is made into a ball (Plate VI) and it is then slightly washed on the outside and preserved along with the previous day's lot. In this form,

* 'Buttermilk' in this connexion is used for liquid curd which has been churned and from which butter has been removed.

PLATE II.

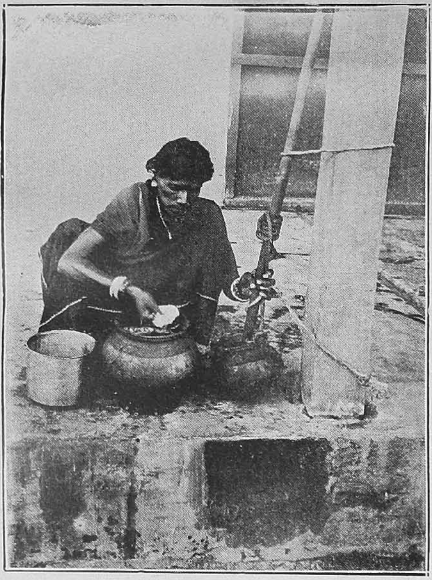


BOILING MILK IN POT. NOTE THE COWDUNG CAKES ON THE LEFT-HAND CORNER.

PLATE III.

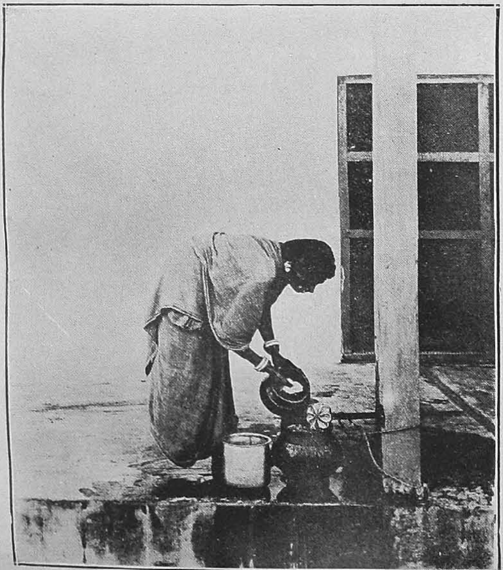
BUTTER-MAKING FROM CURDS. NOTE THE BEATER CHURN EMPLOYED.

PLATE IV.



SKIMMING TOP CURDS FOR BUTTER-MAKING.

PLATE V.

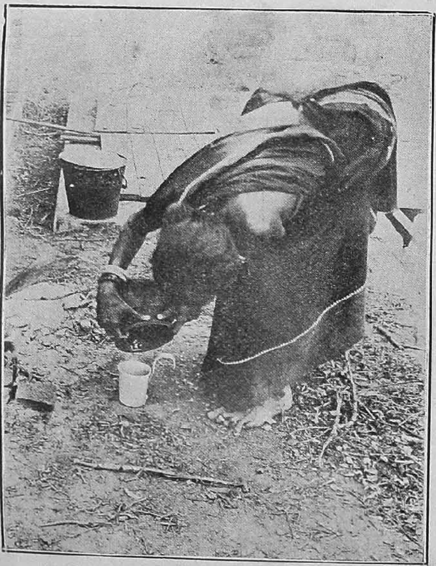


REMOVAL OF BUTTER WITH HAND.

PLATE VI.

FINAL STAGE IN BUTTER MANUFACTURE. NOTE THE STATE OF THE BUTTER IN THE WOMAN'S HAND.

PLATE VII.



STRAINING GHEE.

the butter has encased in it a fairly large quantity of casein, which unless melted at once, will be tainted with an objectionable odour. When a sufficient quantity of butter is accumulated, it is melted over an open fire. The curd present in the butter probably gives aroma to the ghi, and at the same time leaves a sediment. When all the water is evaporated, and the characteristic sound of bubbling ceases, certain kinds of leaves like *Moringa pterygosperma, Gærtn.* or *Murraya Koenigii, Spreng.* are added for flavouring. The ghi is then strained through a cloth and is then ready for the market (Plate VII).

PART II.

In the experiment 10 lb. of Farm buffalo milk which was analysed, was taken each evening, and treated as described above. Both the methods were adopted. The table below gives the details of the experiment. The butter obtained by churning was melted either each morning or after a sufficiently large quantity was accumulated :—

TABLE I.

Date.	Quantity of milk boiled.	Amount of butter fat present in milk boiled.		Butter-milk obtained.	Butter obtained.		Ghi obtained.	
	LB.	LB.	OZ.	LB.	LB.	OZ.	LB.	OZ.
11th March 1918 ...	10	0	10	20	0	11¼	1 (11th–13th)	11¼ (11th–13th)
12th do. ...	10	0	9½	20	0	11½		
13th do. ...	10	0	10	20	0	11½		
14th do. ...	10	0	9	20	0	8	0	6
15th do. ...	10	0	10	20	0	9¾	0	7½
16th do. ...	10	0	9½	20	0	11½	0	8¾
17th do. ...	10	0	11	20	0	11¼	0	8¼
18th do. ...	10	0	10¼	20	0	10½	0	8¼
19th do. ...	10	0	9¾	20	0	11¼	0	9
20th do. ...	10	0	10¼	20	0	11¾	0	9
Total ...	100	6	3¼	200	6	12¼	5	4

During the ten days that this experiment was conducted, 100 lb. of milk whose average percentage of fat was 6·2, produced 6 lb. 12¼ oz. of butter, and 200 lb. of buttermilk. The butter on melting gave 5 lb. 4 oz. of ghi.

In the second method, the milk was treated exactly as above, but in the morning, only the top portion was skimmed and churned. The table below shows the varying quantities of top curd removed from day to day, which is purely arbitrary, depending as it does entirely on the judgment of the worker.

TABLE II.

Date.	Quantity of milk boiled.	Amount of butter fat present in milk boiled.		Quantity of top curds removed.		Curds left over.		Butter obtained.		Butter milk obtained from top curd.		Quantity of broken curd sold mixed with buttermilk.		Ghi obtained.		Percentage of fat in buttermilk.
	LB.	LB.	OZ.	LB.	OZ.	LB.	OZ.	LB.	OZ.	LB.	OZ.	LB.	OZ.	LB.	OZ.	
28 Nov. 1918.	10	0	10¼	3	0	7	0	0	5½	8	0	12	0	0	9	0·3
29 Nov. 1918.	10	0	11¾	3	8	6	8	0	6½	8	0	10	8			0·2
30 Nov. 1918.	10	0	11½	4	8	5	8	0	7¾	8	8	10	0	0	6	0·3
2 Dec. 1918.	10	0	10	2	0	8	0	0	3¾	5	0	11	0	0	2½	...
3 Dec. 1918.	10	0	12	2	8	7	8	0	5½	6	8	10	0	0	4½	0·4
4 Dec. 1918.	10	0	10¾	2	8	7	8	0	6	7	0	10	0	0	4½	0·3
5 Dec. 1918.	10	0	11¾	4	0	6	0	0	6	10	0	10	0	0	5	0·4
6 Dec. 1918.	10	0	10¼	3	8	6	8	0	6½	8	8	9	0	0	5	0·3
7 Dec. 1918.	10	0	9½	3	8	6	8	0	4	8	8	10	0	0	3	0·4
8 Dec. 1918.	10	0	10¾	3	0	7	0	0	5	8	0	10	0	0	4	0·3
Total ...	100	6	12½	32	0	68	0	3	8½	78	0	102	8	2	11½	

Since the quantity of curd skimmed each day varies, the rest which are dependent on it also vary. The butter and ghi obtained by this process is much lower than in the former method, but the price paid for the curd, more than compensates any loss sustained in the diminished quantity in ghi. The quantity of buttermilk added to the rest of the curd depends upon the proper consistency of the curd as judged by the curdwoman, and also upon the quantity of curd originally skimmed. It is usual to make up the curd in this way to nearly the original quantity of milk boiled (vide Table II, column 8). In a total of 100 lb. of milk, of an average of 6·7 per cent of butter fat, 102½ lb. of mixed curd, 43½ lb. of butter milk, and 2 lb. 11½ oz. of ghi were obtained. The percentage of ghi to butter is 77, while that of the butter to curd is 11. The ghi obtained every day varies with the quantity of top curd removed, with the fat content of each day's milk, and with the amount of butter left in the buttermilk. This last varies as shown in the last column, the average being about ·3 per cent of fat.

Let us now consider the economics of ghi manufacture. In the first method where the whole curd was churned and butter made, 5 lb. 4 oz. ghi were obtained from the 100 lb. of milk. At the time of the experiment ghi was selling at 10 annas per lb. and therefore this quantity fetched Rs. 3-4-6. In addition to this there were 200 lb. of buttermilk, which at the rate of 2 pies per pound yielded an additional income of Rs. 2-1-4, making a total of Rs. 5-5-10 whereas the price of 100 lb. of milk if purchased at 1 anna per lb. would cost Rs. 6-4-0.

Taking the second method, namely, skimming the top curd, besides 2 lb. 13½ oz. ghi, 102½ lb.

of mixed curd and 43½ lb. of buttermilk were sold.

	RS.	A.	P.
Therefore 2 lb. 11½ oz. of ghi at 10 annas per lb. was worth ...	1	11	2
102½ lb. of mixed curd at ¾ anna per lb. was worth	4	12	10
43½ lb. of buttermilk at 2 pies per lb. was worth	0	7	3
Total ...	6	15	3

In the former case there was a loss of over 14 annas, and in the latter a gain of 11¼ annas, in the transaction in converting 100 lb. of milk into ghi in each case. In the latter case the profit is entirely due to the curd, which caters to the tastes of a few. It is held that sometimes good curd will fetch 1 anna per lb. and buttermilk 3 pies per lb. At these rates there are the possible profits of As. 2–6 and Rs. 2–8–7 respectively in 100 lb. of milk. In calculating these profits, the writer had so far not taken into consideration the cost of fuel in boiling milk and ghi, the labour entailed in the manufacture of ghi and in the disposal of the products. In doing the experiment it was found that the services of a woman for 3 hours in the morning for churning and selling curd and an hour for boiling milk and ghi were necessary. Half a day's wages for a woman means 1 anna 3 pies to which may be added 3 pies for fuel for boiling milk and ghi, or 15 annas for 10 days. If this amount is added to the expenses already incurred, it will be found that the profits from ghi manufacture will be less still. There are two causes, however, which seem to make it possible for such a bad business to assume such proportions. Firstly, in the majority of cases at least around Coimbatore, many of the agricultural classes enjoy the luxury of buffaloes' or cows' milk for themselves. But a good buffalo would provide more milk than the needs of a small family. This surplus milk, specially that of the evening is converted into curd and ghi such people being content with small profits, if any. Secondly, there is the professional ghi woman, who knowing that the profits of ghi could be extended by adulteration which is not easy of detection, indulges herself in it freely until it becomes an art. It is therefore beyond doubt that the ghi that is purchased from a professional ghi woman is decidedly adulterated, but the writer is not prepared to say to what extent this adulteration goes on. Nor does it appear to be within the scope of this paper to discuss the various adulterants used.

There is still a third method of making ghi, which has come to the notice of the writer, and which is often practised in Indian homes, at least in some parts of the Presidency. It consists in boiling the milk and after allowing it to stand for a while, the cream which floats on the top is skimmed. The rest of the milk is disposed of in the usual way. When the cream is accumulated for a number of days, it is soured and churned. The butter is then melted into ghi. It was thought, therefore, worth while to see how much of fat could be removed from milk in this way and of what nutritive value the rest of the milk will be. This test became specially imperative because the writer on more than one occasion has had misgivings as to the genuineness of the purchased milk as there were traces of boiled cream in suspected samples. It was supposed that the milk must have been boiled overnight, the top cream removed and the rest of the milk sold to the Dairy next morning. The details of the experiment will be found below from which it is evident that half the quantity of butter could be removed in this manner :—

Date.	Quantity of milk boiled.	Amount of butter fat in		Weight of cream obtained in skimming.	Butter obtained from		Ghi obtained from	
		Milk.	Skimmed milk.		Cream.	Skimmed milk.	Cream.	Skimmed milk.
	LB.	OZ.	OZ.	OZ.	OZ.	OZ.	OZ.	OZ.
11th March 1918 ...	10	10	5	6½		3¼		
12th do. ...	10	9½	5¼	6¾	15½	2½	10½	8
13th do. ...	10	10	4¾	8¼		4½		
14th do. ...	10	9	3¾	8¼		3		2¼
15th do. ...	10	10	5½	7¾	16¼	5½	12	4
16th do. ...	10	9½	5¾	6½		5½		4¼
17th do. ..	10	11	7½	7		6¼		4¼
18th do. ...	10	10¼	6	6¼	15¾	6½	12	5
19th do. ...	10	9¾	4¼	9½		3½		3
20th do.	10	10¼	5½	7¾	...	5	...	4

The skimmed cream produced 34½ oz. of ghi which is not a small amount when we take into consideration that the ghi woman would get full price for the rest of the milk. Another aspect which may be of interest is that buffalos' milk which is considered too rich for invalids, could, if boiled and skimmed, be brought down to the richness of cows' milk.

From the experiments made it is clear that the manufacture of pure ghi at the present prices is not a profitable concern and it is beyond doubt that if the tradeswoman makes her profit it cannot be by straightforward means, and it is all the more probable because the chances of detection are by no means easy. It is also seen that in the country method of making butter as much as 3 per cent of butter fat is retained in the butter milk (vide Table I, column 10). With a view to improve this improper separation, the curd was previously treated similarly in all respects, but was churned in an 'end over end' churn, with the result that the same quantity of curd produced 7·5 per cent of butter against the average of 6·7 per cent by the local beater churn and the butter milk on analysis left very little trace of the presence of butter fat. There is therefore room for improvement in this direction. The price of a churn offers the greatest difficulty, but the inculcation of the principles of co-operative dairying is the only hope.

How far other methods could be substituted to bring the present ghi trade into more favourable economic position yet remain unsolved. This is a line along which further enquiry needs to be made.

REPORT ON A TOUR IN THE COCONUT TRACTS OF TRAVANCORE STATE IN DECEMBER 1918.

By H. C. SAMPSON, B.SC.,

Deputy Director of Agriculture, V - VII Circles.

I reached Alleppey on the 5th evening and on the 6th spent the day on Mr. Baker's estate at Kumarakum. Mr. Davey kindly arranged to accompany me there. This is a back-water coconut garden on the banks of the Vembanaad lake from which it has been reclaimed. The process of reclamation consists of clearing mangrove and other wild back-water vegetation, of cutting parallel dykes in the mud for drainage and spreading the earth thus removed on the intervening land. These dykes are all connected together and thus a movement of soil water is effected. The width of the dykes and the distance apart varies in different parts of the estate. In the older plantations, these are close together so that trees planted on the middle of the land strip are about 22—24 feet from those on the next strip. In later planted gardens both the dykes and land strips are much wider and a double line of trees are planted on each strip more or less on the triangle system. This latter system seems much more preferable since navigation in the dykes is rendered more easy (all harvesting is done by boat), the cultivation of the ground is easier and it is easier to keep the dykes open thus allowing greater soil water movement. Cultural and manurial operations are mainly confined to keeping the soil in good mechanical condition and in supplying plant-food to the limited soil capacity in which the roots of the palm can develop.

2. In the hot weather the water is pumped out of the dykes which are then cleaned and deepened, the mud thus obtained being utilized to repair the planted strips which naturally suffer from land denudation during the heavy rains of the monsoon. Quicklime also is largely supplied to keep these soils, which are naturally ill-drained and very rich in organic matter, sweet. The surface soil also is turned over annually but the effects of this were not very apparent as grass very quickly re-establishes itself under these moist tropical conditions. Back-water silt of a coarse sandy

nature and rich in leaf debris is largely used for soil renovation, while where the soil is particularly heavy, this receives coarse sand as a top dressing to alleviate this. It was particularly interesting to me to visit a large property like this under careful and constant supervision and one realizes even with a crop such as this, how necessary careful and constant supervision is. It was also of great interest to me because it showed quite a new aspect of coconut cultivation to what I have hitherto had a chance of observing. Mr. Baker's experience in combating insect-pests is of interest and would probably pay for further investigation.

3. As a preventive against Rhinoceros beetle, Mr. Baker informed me that placing a small piece of 'Marothi' or 'Maruvathi' poonac in the young leaf axil will prevent the beetle from visiting the palm. The red ant of which I have previously made mention in my October report is a very serious pest here in Travancore not only does it tend and rear mealy bugs but it also attacks the men who gather the nuts. Mr. Baker uses white-wash in the case of young trees with which he splashes the crown of the tree and I gather that the effect is that the mealy bug will not thrive where the white-wash is splashed and hence the red ants seek elsewhere to establish the colonies of this pest.

4. The 7th morning I spent with Mr. Davey of Darragh Smail & Co., who has taken up coconut cultivation as a hobby. I visited some of his gardens south of Alleppey, situated on what appears to be a barren, bleached, white sand, very similar to the white sandy soils one sees on the Malabar Coast and which apparently also suffers

in the same way from lack of drainage. I need not further describe the condition of these gardens and the trees as this has already been done by Messrs. Anstead and McRae in last year's Year Book. It was very evident however, what an important part drainage plays in the health and productivity of this tree and it is astonishing how well these trees have grown when in some place they have not been able to spread their roots further than two feet into the soil. Though little difference was observed in the vegetative development of such trees compared with those in other parts where drainage facilities were better, their lack of reproductive development was very marked and I do not see how, with such a limited soil capacity, this can be improved, unless the ground water table can be lowered permanently. One question which suggested itself to me was whether the coconut tree itself did not tend by its matted surface root development to make the soil sour. The indigenous cultivation removes all such root growth annually. Gardens are dug deep and the soil left in small heaps for a month or two, after which time the soil is again levelled; and often these surface roots are collected and burnt on the land. Certainly such roots can be of little use to the tree after the rainy season is over, as any near the surface must either die or remain dormant. If they are dormant then they can be of little use as feeding roots as it is in the dry months after the rains that the greatest fruit development takes place. Another point which also suggested itself was the system of manuring and how far the young tree differs in its manurial requirements to the tree in full bearing. I spent a very interesting morning with Mr. Davey and benefited much from his practical experience in growing coconuts.

5. In the afternoon I visited the State coconut garden to the north of Alleppey with Dr. Kunjan Pillai, the Director of Agriculture. This is a collection of reputed varieties of coconuts from all parts of Travancore as well as a few varieties from Ceylon and elsewhere. The appearance of the soil here is very similar to that described in my morning's visit to Mr. Davey's gardens but has the great advantage of not having a pan underneath to hold up the water level. The agricultural practice adopted here is based much more on indigenous methods though these have been considerably developed and improved ; certainly one could not wish to see better development in a young garden than these trees represented. At the same time it was impossible to compare the growth with that in Mr. Davey's gardens as the drainage and soil water conditions were so different. The soil water table here was also high, but, not having any impervious pan beneath, soil water movement was much more active. The main difference between the cultivation in this garden and the indigenous practice was in the method of manuring. Manure was applied in a wide radius of some 6—8 feet instead of immediately below the trunk and it was gratifying to note how in adjoining gardens this improvement had been adopted and also what great attention is now given to the question of manuring. From here we visited some private gardens further north from the town where the owners had adopted departmental methods of cultivation and manuring with evidently most satisfactory results.

6. The Department, I gathered, was very largely a pioneer in planting these sandy soils and now very large areas of young well grown gardens are to be seen. One mistake was made however and that was in the spacing which is only 24 feet. At the time of planting it was never expected that such splendid development was possible on these sandy soils. I do not mention this in a spirit of criticism, as Dr. Kunjan Pillai himself admitted to me his error, but I mention it as so many coconut growers on the West Coast are satisfied with this spacing which, though it may be ample for neglected and unmanured gardens, is certainly insufficient for a properly manured and managed property which I hope in time to see the rule and not the exception.

7. On the same evening I left for Quilon, being accompanied by Mr. Anantarama Ayyar, one of the Department Assistants, and next day went out to see a noted garden near Paravur. I went here as I wished to see something of the paramba cultivation which is of such importance in Malabar, but I was very disappointed, as the garden had been allowed to suffer from neglect and was in a very poor condition. It was instructive however in that it shows how essential proper care and supervision is if coconuts are to be grown for profit. One could see that it had at one time been a fine property but was so no longer.

8. Returning north from Quilon the same evening I halted at Kayankulam to see some gardens at Pallikal. The nuts from here are noted throughout Travancore and Mr. Thomas, one of the principal residents of the place, has not only developed a nursery trade in seeding coconuts and

seed-nuts, but pays great attention to the question of seed selection. Some of his trees give very large nuts and he has obtained as much as 1 lb. of copra per nut from some of his trees. When good nuts take 1,700—1,800 to the candy of 622 lb., some idea of the size of these nuts can be gathered. Mr. Thomas had a very neat gauge designed by himself for testing the thickness of the husk when selecting his seed-nuts and he showed me some of his dried seed-nuts which measured 36—37″ in circumference with less than 1″ thickness of husk.

9. From here I returned to Kayankulam. Around the bungalow fully 40 per cent of the coconut trees were suffering from disease. I was told it was the disease which Butler described some years ago but Mr. McRae says from my description, it is probably the leaf disease mentioned in his article in the last year book. At Kayankulam I noticed two items of interest one being the country wet land plough which is furnished with a detachable plough point made of bamboo, a wide point very similar to that of an English plough. I also witnessed the wet land labourer working his mammotie. This implement has a long handle some 5—6 feet long, with a short stiff blade at an angle of about 60°. Several men stand in a row and all keep time with their leader every mammotie enters the soil simultaneously, the men springing forward as they strike the ground. The soil which is cut is then jerked backwards some 3 feet. After a strip is thus dug some 3 feet wide, they form into line at right angles to their previous work and go over the same ground again. It looks much more of a ceremonial dance than real work but the work done is very effective.

10. From here I returned to Alleppey and spent one evening visiting some coast gardens with Dr. Kunjan Pillai and was surprised to see how even here, where fish debris was, one would have thought sufficiently plentiful, to render systematic manuring unnecessary, the trees were carefully manured with ashes and either prawn skin or sardine. I saw one very nice 2-year old nursery planted out 3′×3′ (in the coast gardens larger trees are preferred) and even these showed evidence of having been carefully manured with prawn skins.

11. I left Alleppey on the 11th evening to return to headquarters and was sorry I was unable to stop longer as there is much which I still wished to see and a great deal yet to learn. I am much indebted to the Travancore Darbar and to Dr. Kunjan Pillai for the assistance they rendered me. One point about coconut planting here was that all planting is done on the surface instead of in pits as in many parts of Malabar. The only place I saw, pit planting and even these were shallow, was in the dryer zone south of Quilon.

PEARS FOR JAM-MAKING.

By G. A. D. STUART, B.A., I.C.S.,

Director of Agriculture.

During 1918 an investigation was made into the possibility of manufacturing jams for the Army in India. With the close of the war the matter has now been dropped, but the following information which was collected is worth putting on record. In the opinion of Mr. Frank Elmore, a jam-making expert who was brought over by the

Government of India, the most promising fruit for jam-making in Southern India is the hill pear. One notices the fruit being sold at railway stations and bazaars throughout the south of the Presidency in the season from July to October. Local enquiries as to the quantities available elicited the following information:—

1. *Nilgiris, especially round Kotagiri.*—Annual export 750 to 1,000 tons. This all passes through Mettupalaiyam market.

2. *Shevaroys.*—Annual export at least 300 tons.

3. *Palnis, Kodaikānal, etc.*—Annual export about 400 tons.

Of the total quantity purchased only some 175 tons was booked by rail,—mainly to Madras. The rest appears to be moved by road to various markets in the south. The price at Mettupalaiyam was about Rs. 60 per ton.

The quantity exported to the plains could probably be considerably increased if a better price were offered.

FOMES LUCIDUS (LEYS), FR., ON *ACACIA MELANOXYLON*, R. BR., AND *PONGAMIA GLABRA*, VENT.

BY W. MCRAE, M.A., B.SC.,

Government Mycologist.

Large full-grown trees of *Acacia melanoxlyon* in parts of Kotagiri and Coonoor in the Nilgiri district are dead and dying. The affected trees occur in considerable numbers and extend over whole hill-sides. From observing the trees as they stand it appears that the first prominent symptom of disease is the withering of the branches on the topmost part of the tree. They become leafless and stand out like antlers conforming to the popular description of a stag-headed tree. The branches continue to die till those on the upper half of the tree are entirely leafless and dead. Owners of estates say that it takes a year or two for an infected tree to get to this stage and that the lower branches die more rapidly. The ultimate state is a dead leafless tree. Only mature trees were affected. Young trees showed no outward sign of disease. The sporophore of a polyporous fungus was found on seven of these trees—two living fructifications and the remnants of a dead one on a tree with about one-sixth of the upper part dead, four on a tree a little more advanced, one on a tree half dead, two on two dead trees and two on the stumps of two trees that had been felled. They occurred usually just above ground level but two were found about two feet higher. From one to four sporophores were found on a tree.

The sporophore was horizontal, the largest projected six inches and was eight inches broad. The shape was flabelliform, reniform and sub-circular but in one case the pileus was simply a downward sloping knob. Sporophores occurred singly, one above the other from a common base, or in some cases were imbricate. The pileus was dark reddish brown gradually changing to yellow and cream at the edge. The brown part was smooth and varnished but the cream tinted part was dull. Vigorously growing specimens had a thin viscid coating which on drying changed to a hard varnish. The surface had concentric lines and longitudinal undulations or was irregularly waved. The edge was even or irregularly crenated. The hymenial surface was inferior, pale cream or white and the pores were minute. The interior of the sporophores was brown, fibrous and arranged in radial bands. Towards the base it was about two inches thick and at the edge about a quarter of an inch. In these specimens the stipe when present was very short. The spores, borne four on a basidium, were pale yellowish brown, ovoid, had a hyaline cap, were slightly truncated, and had radial lines in the wall. They measured 8·2 to 12·7 × 6·1 to 8·6 *u*, average 10·8 × 7·9 *u*. This fungus agrees with the description of *Fomes lucidus* (Leys), Fr.

One tree that was almost completely dead, the lower branches only having green leaves, and that bore a fructification, was felled and examined. The roots on one side were all dead as was also one side of the stem to a distance of about three feet from the ground and almost half of the cross section. The wood was soft and spongy with plates of mycelium along the medullary rays. Fungus hyphæ were found in the cells of the wood for several inches beyond the soft portion but the cambium region of the other side of the tree was living and contained no hyphæ. The roots too on this side of the tree contained no hyphæ. No other wood-destroying fungus was found and the upper dying branches were not attacked by a die-back fungus. There is thus good reason for the presumption that this fungus is the cause of a root-disease in *Acacia melanoxylon*, R.Br., on the

Nilgiri Hills. This root-disease is encouraged by the fact that the wood-cutters when felling trees always leave one to two feet of stump above ground, where it remains till it rots. The commonest trees that were growing along with *Acacia melanoxylon* were *Eucalyptus globulus*, *Acacia dealbata*, *Cupressus sempervirens* and *Cinchona officinalis*, but none of them were affected.

A fungus similar in all details except that the stipe was better developed and the specimens were rather larger was found growing from the larger roots and the stem of a full-grown specimen of *Pongamia glabra* in Mr. Anstead's compound in Bangalore. The spores measured 9·2 to 12·3 × 6·1 to 8·2 *u*, average 9·9 to 7·1 *u*. It has produced regular crops of sporophores for at least three years. The tree has two main stems branching from ground-level, or it may be that two trees are growing in very close contact. Which it is cannot be determined without cutting down the tree and it is being left for observation. The upper part of the branch system of one of these has been gradually dying back for over two years and the tree is almost dead. During this time the other had shown no signs of being infected. Sporophores were found on the roots and stem of the former only. This year, however, the other shows signs of dying and sporophores are appearing on its roots. No other fungus that can be held responsible for the death of the branches has been found. Thus there is strong presumption for considering that *Fomes lucidus* (Leys), Fr., is also parasitic on *Pongamia glabra*, Vent.

In the Indian Forester, Vol. 35, pages 514 to 518, 1909, Dr. Butler mentions several other trees in North India on which *Fomes lucidus* is suspected to be parasitic.

NOTE ON THE FLORA OF THE TINNEVELLY DISTRICT.

BY RAI BAHADUR K. RANGA ACHARYA, M.A.,

Government Lecturing and Systematic Botanist.

The Flora of the Tinnevelly district is very interesting in several respects. It may be considered to be an epitome, as it were, of the whole of the Madras Presidency, as almost every feature of which is repeated within this area. This district occupies the southernmost part of the tract of country and is separated from the remainder of the Presidency by a lofty transverse range of mountains (Palni and Sirumalai Hills) running from west to east and diminishing in elevation eastward. This transverse range insulates in a very remarkable way the southern tract of the Presidency, which is sheltered from the south-west monsoon by the high mountains of Travancore on the west and from the north-east monsoon by this range to the north, and by the island of Ceylon in the east. As a consequence of this peculiar geographical position the climate in most parts of the district is hot and dry without any humidity.

The rainfall towards the east is small in amount and it gradually increases westward towards the hills. At Courtallam the average rainfall is 40 inches and in the hills of Nāngunēri and Ambāsamudram it is 60 inches on the hills and much less in the plains (minimum 20 inches).

Even in the hills themselves there are local variations in the rainfall.

The district consists of two distinct regions, the eastern and the western. The eastern region is a vast plain extending from about the base of the hills to the shore and the western region consists of the southernmost end of the Western Ghauts separated from the long chain by the Palghat gap.

The eastern region is generally very hot owing to its peculiar position resulting in the shutting off of the monsoons. In the drier flat parts of this region sandy plains covered with short grass and herbs alternate with undulating downs either bare or clothed with dense thickets of thorny shrubs. The vegetation supported by this region is more or less similar to the plants growing on the eastern side of this Presidency from Ganjām to Cape Comorin, although there may be well defined areas with different sets of plants, and hence distinguishable one from the other, while at the same time we meet with plants of very wide and even distribution.

The sea especially in the neighbourhood of Tuticorin abounds in sea-weeds. We always find on the wet sand small heaps of sea-weeds mostly consisting of the genera, *Valonia*, *Udotea*, *Gracillaria*, *Cymodocea* and *Chætomorpha*. There are over a hundred species flourishing in these parts. The following are, however, the most common species:—*Caulerpa scalpelliformis*, *C. plumaris*, *C. peltata*, *C. sedoides*, *Saragassum Wightii*, *S. dentifolium*, *Udotea flabellata*, *Dictyurus purpurascans*, *Polysiphonia corymbosa*, *Valonia Forbesii*, *Halimeda tuna*, *Turbinaria conoides*, *Gracillaria* *multipartita, S. lichenoides, G. tænioides, Ulva fasciata, Enteromorpha intestinalis* and *Chætomorpha æra.* Besides these we find in the seashore in shallow water the monocotyledonous aquatics, *Cymodocea serrulata, C. ausiralis, Halophila ovata* and *Halophila stipulacea*, Asch. (a species not previously recorded from India). The dry loose shifting sand near the sea supports a very open vegetation, consisting of only a small number of species. We find plants dotted over here and there and most of them are pure halophytes. The grass *Spinifex squarrosus* with its large and conspicuous inflorescences is met with everywhere, forming in many places a pure association to the exclusion of other species of plants. The zone next to this abounds in xerophytic halophytes, consisting of the Chenopodiaceous plants, *Salicornia brachiata, Arthrocnemum indicum, A. glaucum, Suæda maritima, S. monoica, S. nudiflora* and *Sesuvium portulacastrum* and *Atriplex.* Further inland we find plants which are mostly annual with a sprinkling of perennial herbs with creeping rhizomes and the plants usually flourishing here consist of the species, *Lippia nodiflora, Solanum xanthocarpum Vernonia cinerea, Cyperus arenarius, Zoysia pungens, Indigofera enneaphylla* and *I. trita.* Amidst these here and there are found *Salvadora persica* and *Thespesia populnea.* Clayey spots abound in the sedge *Cyperus bulbosus* and the grasses, *Sporobolus virginicus* and *Aeluropus villosus.* Saline marshes support the mangrove plants, *Avicennia officinalis, Pemphis acidula, Scævola Lobelia* and *Lumnitzera racemosa.* These remain stunted and small and never become bushy and dense as at Coringa and one or two other places on the East Coast. This is so, as the marshes are shallow and not extensive.

As we proceed inland we pass gradually to the flora so characteristic of the Carnatic and the Coromandel Coast. But the herbaceous and the shrubby vegetation of this region is very much stunted in growth and is very meagre as regards number, compared with similar regions in other districts, except of course for a few months after the rains every year. The poor stunted state of the plants is due to the very dry condition of the soil and the extreme heat, the resulting of the shutting off of the monsoons from the district by the hills already referred to and by the island of Ceylon. Xerophilous plants such as *Barleria cuspidata*, *Lepidagathis pungens* and columnar leafless *Euphorbias* occupy these tracts, and from amidst them rise trees such as *Acacia arabica*, *A. Latronum*, *A. planifrons* (conspicuous on account of its flat topped head). Other common trees such as the Banyan and other Ficuses, *Terminalia tomentosa*, *Bassia longifolia*, *Melia Azadirachta*, and *Thespesia populnea* are found here also, as elsewhere in the Presidency.

The black cotton soil supports a vegetation consisting of some or other of the following plants:—*Chrozophora plicata*, *Aristolochia bracteata*, *Triumfetta rhomboidea*, *T. rotundifolia*, *Indigofera trita*, *Corchorus trilocularis*, *Momordica cymbalaria*, *Withania somnifera*, *Cassia auriculata*, *C. obovata*, *C. angustifolia* (though cultivated, run wild in some places), *Cynodon dactylon*, *Panicum Isachne*, *Andropogon pumilus* and *A. pertusus*.

There is not much change in the character of the vegetation until we come up to the base of the vicinity of the hills. As we approach the hills, scrubby jungles consisting of the usual thickets composed of trees and shrubs such as *Zizyphus œnoplia*, *Z. jujuba*, *Z. rugosa*, *Z. xylopyrus*, *Canthium parviflorum*, *Alangium Lamarckii*, *Albizzia*, *Capparis horrida*, *Terminalia chebula* and *T. belerica*, make their appearance. Though there is a great uniformity of vegetation with strong affinities to the flora of the plains elsewhere in the Presidency, yet here and there we meet with special features. The region of the foot of the hills and the lower elevations of the hills on the way to Naterikal is striking on account of the dominance of *Notonia grandiflora*, *Ehretia ovalifolia* and *Albizzia amara*. A small leaved species of *Anogeissus*, *A. pendula*, not recorded previously from South India, occurs scattered here and there, but is more common and conspicuous in the reserves on the Velliyur side.

The foot of the hills near Pāpanāsam, for instance, is characterized by the predominance of *Coleus spicatus*, *Asystasia coromandeliana*, *Sarcostemma intermedium*, and *Mundulea suberosa*. At Courtallam such places harbour the common plants of the plains, but *Indigofera uniflora*, *Oldenlandia paniculata*, *Canthium parviflorum*, *Phyllanthus reticulatus* and species of *Sida* were very prominent. The compositaceous plant *Gynura lycopersicifolia* so far known to occur only here, is very abundant. The introduced *Lantana* has established itself here firmly and is spreading very rapidly on every side. Some of the neglected coffee estates are completely overrun by this plant. Another plant which is spreading aggressively is *Stachytarpheta indica*, the moist condition of the soil being very favourable for its growth. The sensitive plant, *Mimosa pudica* was a rare thing some fifteen years ago, but now it has become quite common, and if it is not checked from spreading at a very early date, it is certain to become a serious pest as it has already done in Coorg and certain parts of Malabar.

At the foot of the Kalkad hills we find *Barleria cuspidata*, *Erythroxylon monogynum*, *Dalbergia spinosa*, *Indigofera aspalathoïdes* and *Hibiscus micranthus* dominant with a sprinkling of the common plants such as *Vicoa auriculata*, *Sida carpinifolia*, *S. veronicaefolia*, *Tephrosia purpurea*, *Cassia auriculata*, *Vitis quadrangularis*, *Dregea volubilis*, *Tylophora asthmatica* and *Rivea hypocrateriformis*. The nature of the vegetation does not change at the foot of the hills and even up to a certain height. For instance, from Papanasam to Mundandurai, we find only plants characteristic of the plains forming the bulk, although plants such as *Givotia Rottleriformis*, *Stenosiphonium Russellianum*, etc., usually flourishing at low elevations are also found mixed with them. In the neighbourhood of Mundandurai, *Strobilanthes*, *Cadaba trifoliata*, *Strychnos colubrina*, *Murraya exotica*, *Abutilon crispum*, *Zornia diphylla*, *Vitex leucoxylon*, *V. altissima*, *Eugenias*, and a few species of *Zizyphus* and *Grewia* abound. Here again we find a mixture of plants of the plains and the lower elevations, but plants such as *Aglaia Roxburghiana*, *Eugenia rubicunda* (a species recorded only from this district), *Sapindus bifoliatus*, *Croton Klotzchianus*, *Polyalthia cerasoides* and *Alphonsea sclerocarpa* (a species confined to Tinnevelly and Ceylon) predominate.

The frequent denudation of the forest on the lower slopes of the hills by the clearing of the coupes exerts a profound influence on the nature of the vegetation. Old plant communities are eradicated, the soil gets exposed and is rendered fit for many species of plants. Areas recently cleared are clothed with a vegetation most varied in nature and composed of a large number of species. The new species occupying the cleared area are species occurring scattered singly at the edge of the forest or in the vicinity. Most of the plants are annuals, perennials being very rare. The plants flourishing on the plains generally creep up and occupy the area. The older clearings differ from the more recent ones in having a large number of perennials and at the same time the vegetation tends to become more uniform in its composition and character. The lower slopes of Kalkad hills, for about three miles have been thus denuded and so the vegetation in this region partakes the characteristics of the flora of the plains.

The slopes of these hills are all exposed to sun and rain alternately. The period of dry season is very prolonged in the case of lower slopes and as we ascend it becomes shorter and shorter. So we find deciduous monsoon forests on the slopes. The lower forests are xerophytic and the higher mesophytic in character.

The higher elevations of these hills are clad with forests in which we find trees and plants characteristic of the Western Ghauts to a large extent. Still higher elevations support plants of a temperate region and the vegetation is extremely luxuriant containing many and indeed composed almost exclusively of the species of the great peninsular chain. Amidst these sub-tropical rain-forests on the slopes, here and there, we find open spaces bearing clumps of shrubs, swards of grass and a rich herbaceous vegetation, the larger trees being confined to the ravines.

As we proceed higher up towards Kannikati, Anonaceous species become very common thus showing Malayan affinities. Other species that are also predominant are those of *Diospyros* and *Grewia*. The two species *Diospyros Barberi* and *Grewia pandaca* were recently discovered to be new species confined to this region. A species of *Aglaia* growing between Mundandurai and Kannikati was found to be a new species and it was named *Aglaia Barberi* by Mr. Gamble. Besides these on the rocks in the Tambraparni river especially near Mundandurai were found growing two new species of plants *Lawia zeylanica*, var. *malabarica*, and *Farmeria indica* both belonging to the same interesting and peculiar family *Podostemonaceæ*. The latter *Farmeria indica* is an endemic species. Another herbaceous plant *Ionidium travancoricum* endemic to Tinnevelly and Travancore hills is very abundant there, as well as on the Kalkad hills on the way to Naterikal, and to Mahendragiri hill. The creeper *Pyrenacantha volubilis*, a Ceylon plant, occasionally met with in the Avadi forests near Madras and on the Sirumalai hills in the Madura District is abundant here and also in and around Naterikal. Several scandent shrubs such as *Combretum*, *Calycopteris*, and climbers such as *Cissampelos Pareira*, *Bryonia laciniosa*, *Zehneria Hookeriana*, *Z. Baueriana*, *Aristolochia indica*, *A. Roxburghiana* and *Passiflora Leschenaultii* are fairly abundant.

The undergrowth consists of a very rich herbaceous vegetation composed of plants of the orders Compositæ, Rubiaceæ, Leguminosæ, Acanthaceæ, Labiatæ, Geraniaceæ, Scitamineæ and Gramineæ. However the most widely occurring and striking species are *Curculigo Finlaysoniana*, *Commelinas*, *Scutellaria violacea*, *Sporobolus diander*, *Panicum patens* and *Oplismenus compositus*.

On moist rocks we find *Aneilema paniculatum*, *Cyanotis arachnoidea*, *Pouzolzia* two or three species, *Hibiscus surattensis*, *Impatiens balsamina*, *Impatiens grandis*, *Didymocarpus tomentosus* and *Rottlerianus*, *Begonia floccifera*, *B. malabarica*, *Pteris aurita*, *Hemionitis arifolia*, *Cheilanthes mysorensis*, *Drynaria quericifolia* and *Selaginellas*.

On the Mahendragiri hill on such rocks are found *Drosera indica*, *D. Burmanni*, *Sopubia delphinifolia*, *Utricularia reticulata*, *U. Wallichii*, *U. orbiculata*, *Eriocaulon* two species, one small and the other larger, *Cassia mimosoides* and *Ophioglossum fibrosum*.

The vegetation of the Kalkad hills is more or less similar to that of Papanasam and Mundandurai hills. In the lower elevation on the Kalkad hills herbaceous plants are abundant the most widely spread ones being, *Crotalaria prostrata*, *Crotalaria albida*, *C. biflora*, *C. calycina*, *Polygala javana*, *P. elongata*, *Indigofera* two or three species, *Desmodium latifolium*, *Euphorbia cristata*, *E. hirta*, *Knoxia corymbosa* and *K. Heyneana*, *Orthosiphon diffusus*, *Leucas* two or three species, *Tephrosia tinctoria* and *Rothia trifoliata*.

On the higher elevations of the hills of this district we have evergreen sub-tropical forests.

Viewed from a broad point of view these hills no doubt present the same characteristics as those of the Anamalais, Palnis and Nilgiris, but as we proceed southwards we notice features peculiar to the district.

The forests are evergreen and are always moist and therefore the trees in the sholas are all invariably tall. Several plants that usually remain as shrubs or small trees in other places on the Western Ghauts, here grow to tall trees. For instance the verbenaceous species *Clerodendron infortunatum*, generally a shrub elsewhere, becomes a tall tree in several sholas on these hills.

On the Kalkad hills the vegetation in and around Naterikal and between Naterikal and Sengalteri is both interesting and quite characteristic of these hills. There are a number of sholas in this region abounding in tall trees, such as *Nephelium Longana*, *Myristica* two or three species, *Pittosporum floribundum*, two or three species of *Litsæas*, *Actinodaphne*, *Michelia nilagirica*, *Elæocarpus Munronii*, *E. serratus*, *E. oblongus*, *Eugenias*, *Mangifera*, *Xylia dolabriformis*, *Isonandras*, *Acronychia laurifolia*, *Daphniphyllum glaucescens*, *Diospyros oocarpa*, *D. ebenum*, etc. The bulk of the undershrub consists of low trees such as *Vaccinium Leschenaultii*, *Ochna Wightiana*, *Antidesma ghæsembilla*, *Linociera*, *Clausena indica*, *Zanthoxylum*, *Murraya exotica*, *Euonymus dichotomus*, *Grewia Barberi*, *Connarus Wightii* and another species of *Connarus*, *Viburnum punctatum*, *Leea sambucina*, *Calamus Pseudo-tenuis*, *Polyalthia Korintii*, *Podocarpus latifolia* and many shrubby and herbaceous plants of the families, *Acanthaceæ*, *Rubiaceæ*, *Compositæ*, *Labiatæ*, *Euphorbiaceæ*, *Urticaceæ*, *Cyperaceæ*, Grasses and Ferns. The Acanthad *Diotacanthus grandis*, an endemic species, is found in abundance in all the sholas on these mountains. Other plants which seem to be peculiar to these hills and also pretty widely distributed are *Phyllanthus Baillonianus*, *Solanum vagum*, *Ophiorhiza eriantha* and *O. Mungos*. By the sides of the streams and ravines we find *Asystasia travancorica*, *Impatiens Hensloviana*, *I. grandis*, all over the hills and between Naterikal and Sengalteri these as well as *I. Gardneriana* and *I. uncinata*. In most of the sholas near and round Naterikal the velvety leaved orchid *Anœctochilus regalis* is abundant in moist shaded places. *Liparis atropurpurea* is another orchid occasionally found in these sholas by the sides of streams. Other plants harboured by such situations are *Dorstenia indica*, *Calanthe Masuca*, *Diotacanthus albiflorus*, *Hedyotis albonervia*, *Coleus malabaricus*, *Barleria cuspidata*, *Pilea trinervia* and *Elatostema lineolatum*. On trees and rocks especially in moist situations are seen *Cymbidium aloifolium*, *Eria pauciflora*, *Peperomia reflexa*, *P. dindugulensis*, *Saccolabium filiforme*, *Hoya pauciflora* and *Lycopodium Wightii* and *L. Selago*.

As the forest remains moist for the greater portion of the year tree ferns, epiphytes, and shade plants with large leaves are abundant in the forests between Naterikal and Sengalteri.

The undergrowth in the sholas of these hills consists mostly of Ferns, *Selaginellas*, *Hydrocotyle javanica*, *Begonia fallax*, *B. malabarica*, *B. floccifera*, *Plectranthus menthoides*, *Peliosanthes courtallensis*, *Pancratium triflorum*, species of *Psychotria* and *Lasinanthus*, *Chasalia curviflora*, *Ophiorhiza eriantha*, several species of sedges and grasses. In some sholas extensive patches of *Viola distans* and *Panicum pilipes* are fairly common. However among the many plants forming the undergrowth the plants *Piper subpeltatum*, *Dianella ensifolia*, *Curculigo Finlaysoniana*, *Begonia floccifera*, *Desmodium dolabriforme*, and ferns of the genera, *Fteris*, *Pellæa* and *Polystichum* are particularly noteworthy, as they are dominant in several sholas. Long stretches of *Ochlandra travancorica* are met with between Naterikal and Sengalteri. This and another species of bamboo form impenetrable thickets so dense that nothing grows underneath.

Grassy downs so characteristic of the higher elevations of the Palni and Nilgiri mountains do not occur on these hills. There are, however, grassy swards of smaller dimensions consisting of the usual hill grasses, *Andropogon zeylanicus*, *Andropogon nardus*, *A. schœnanthus*, *Anthistiria ciliata*, and two or three species of *Arundinella*. On the Mahendragiri hill on rocks amongst the grassy swards the orchid *Arundina bambusifolia* is very abundant. Plants conspicuous amidst grass are *Pimpinella Candolleana*, *Bupleurum mucronatum*, *Senecio ludens*, *Exacum atropurpureum*, *Lilium neilgherrense*, *Swertia affinis*, *Centratherum reticulatum*, *Heracleum rigens*, *H. Sprengelianum* and *Phyllanthus simplex*.

Amidst grass in the neighbourhood of Mango shola a species of *Crotalaria* is very abundant and this does not match with any of the Indian forms and appears to be a new species. Several species of *Vernonias* occur in the sholas and in open places about Naterikal and Sengalteri. Of these a narrow leaved form occurring also on the Agastiyar hill, is new to science and was recently named *Vernonia Ramaswamii.* In and around Sengalteri bungalow there is growing an arboreous *Vernonia* awaiting identification. And yet another delicate leaved *Vernonia* with very delicate small heads growing in sholas between Sengalteri and Naterikal appears to be a new species.

On all the hills from Kannikatti to Mahendragiri we find the endemic species *Hedyotis purpurascens*, a plant very conspicuous on account of its massive violet inflorescence. All round Sengalteri, Naterikal and Kannikatti and also on Mahendragiri a very remarkable plant *Anisochilus robustus* of the family Labiatæ with very large fleshy leaves and a main stem four to eight inches thick (a character rather unusual for the family) is very abundant though scattered. This is also an endemic species. Another Labiate, also endemic to Tinnevelly hills, *Orthosiphon comosus* is very common amidst grass and is most attractive when in flower, on account of its purple flowers and bracts forming terminal spikes. A very pretty climbing *Senecio* with yellow flower heads, abundant in the valley a little below Sengalteri and on Mahendragiri is another new species confined to these hills and this was named *Senecio Calcadensis.*

As already remarked the sholas consist of very tall trees and the main bulk of them are such as are met with elsewhere on the Western Ghauts. However, there are also many species of trees peculiar to these hills. All along the streams and also within the sholas, we find the trees *Mesua ferrea, Mesua coromandeliana* and *Eugenia rubicunda.* The trees *Hopea parviflora, Balanocarpus* *utilis*, *Pœciloneuron indicum*, *P. pauciflorum*, *Xylopia parvifolia* and *Ormosia travancorica* are very common and occur only on these hills and in Travancore. Another tree *Filicium decipiens*, a Ceylon species is also very abundant.

The teak tree flourishes in several places at the base of the hills, but everywhere of poor growth only. The most valuable timber trees of these mountains are the following:—*Acrocarpus fraxinifolius*, *Artocarpus hirsuta*, *A. integrifolia*, *Balanocarpus utilis*, *Bischoffia javanica*, *Bridelia retusa*, *Chloroxylon Swietenia*, *Diospyros Barberi*, *D. ebenum*, and two other species. *Hardwickia binata*, *Heritiera papilio* two or three species of *Eugenias*, *Gluta travancorica*, *Myristica attenuata*, *M. laurifolia*, *Eugenia dalbergioides*, *Pterocarpus marsupium*, *Pterospermum rubiginosum*, *Schleichera trijuga*, *Terminalia tomentosa*, *T. paniculata* and *Xylia dolabriformis*.

Orchids are fairly common on these hills. Among ground orchids, *Calanthe Masuca*, *Anæctochilus regalis*, *Liparis atropurpurea* are fairly common and *Pogonia carinata*, *Spiranthes australis*, *Habenaria jantha* and *Disperis zeylanica* also occur but are not common. Several species of *Dendrobium*, *Eria pauciflora*, *Pholidota imbricata*, *Saccolabium* (two species), *Oberonia* (two species) and *Cymbidium aloifolium* are other common orchids. The orchid *Ania latifolia* is confined to Tinnevelly and Travancore.

Grasses are very well represented both on the hills and the plains. All the genera and species found in the Presidency occur in the district. A new species of *Cynodon* named *Cynodon Barberi*, of very wide distribution, occurs here also.

Many of the plants described and illustrated by Col. Beddome in his "Flora Sylvatica" and "Icones Plantarum" are those found on Kalkad, Kannikatti and Sivagiri hills. Plants so far known to be endemic to Tinnevelly hills (and Travancore also in some cases) are the following:—*Aglaia Barberi, Anisochilus robustus, Andrographis elongata, A. Viscosula, A. scaber, Anaphyllum Beddomei, Balanocarpus utilis, Centratherum molle, Coleus parviflorus, Cinnamomum gracile, Didymocarpus Rottleriana, var. Wightii, Diospyros Barberi, Diotacanthus albiflorus, Diotacanthus grandis, Elettaria Cardamomum, Eugenia rubicunda, Elatostema sp., Farmeria indica, Grewia Barberi, Hedyotis albo-nervia, Hedyotis purpurascens, Hedyotis viscida, Homalium travancoricum, Ionidium travancoricum, Leptonychia moacurroides, Mallotus Beddomei, Psychotria nudiflora, Ochlandra travancorica, Orthosiphon comosus, Pterospermum obtusifolium, Senecio calcadensis, Vernonia travancorica, Vernonia Ramaswamii* and two other species yet to be named.